EFFECT OF MOMENTARY EXTERNAL FIELDS
ON THE
RETENTIVITY OF PERMANENT MAGNETS
OF RECORDING WATTMETERS

L. E. SIMMONS

ARMOUR INSTITUTE OF TECHNOLOGY

1909

537.7
Si 4

Illinois Institute
of Technology
Libr…

AT 160
Simmons, Leslie E.
A study of the effect of
momentary external fields

13

A STUDY OF THE EFFECT OF MOMENTARY EXTERNAL FIELDS ON THE RETENTIVITY OF THE PERMANENT MAGNETS OF RECORDING WATTMETERS

A THESIS

PRESENTED BY

LESLIE E. SIMMONS

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

Approved
A. A. Radtke
Prof. of E.E.

L. C. Monin
Dean of Cult. Studies

H. M. Raymond
Dean of Eng. Studies

- INDEX -

21512

A STUDY OF THE EFFECT OF MOMENTARY EXTERNAL FIELDS ON THE RETENTIVITY OF THE PERMANENT MAGNETS OF RECORDING WATTMETERS.

The object of this investigation was to determine the influence of momentary external magnetic fields, such as those produced in a wattmeter by a short-circuit on the load side, upon the drag magnets of a D.C. recording wattmeter; and to discover, if possible, some position of the field coils relative to the magnets in which the effect of such a field might be considered as negligible.

In order to pursue this investigation, three factors, in the main, were necessary. These were,(1) a D.C. recording wattmeter using permanent magnets as its retarding device, (2) a momentary magnetic field of sufficient intensity, and (3) some means of adjusting the direction of this field to any desired angle relative to the field of the permanent magnets.

The meter used was a Scheefer recording wattmeter, 110 volts, 5 to 10 amperes capacity, and was selected merely because of its availability and convenient structure. The outer case, back, and gear train were removed, and the meter attached to wooden blocks screwed to the back of a meter supporting board. The non-inductive resistance coil was placed upon the base of the meter board, using the same connecting wires that were originally in the instrument. Plate I shows a photograph of the meter when mounted.

When the meter is normally operated, the momentary field would be produced by a short circuit on the load side, as before

stated. To have used this method in the present instance, however, would have been undesirable, as the sudden rush of current through the series coil would have caused fluctuations in the voltage and at least temporarily have changed the resistance of the coil. Still another objection was that the series coils were firmly attached to the meter, making it impossible to fulfill condition (3) as stated above. Accordingly, an extra set of series field coils, similar in all respects to those attached to the instrument, was mounted on a rectangular brass bar, and this secured to a brass shaft by means of a set screw at a distance above the disc equal to that of the meter coils below it. (See Plate I). This shaft was pointed on the lower end and set vertically into the upper bearing of the main meter shaft. The upper end of the auxiliary shaft carried a horizontal pointer which swept over a semicircular scale, graduated from 0^{0} to 180^{0}. The terminals of the coils were free to move, permitting the coils to be placed in any desired position, where they could be firmly secured by a cord. The momentary field was secured by short-circuiting the auxiliary coils through a piece of 50 ampere fuse wire, firmly connected to terminals three inches apart. This fuse required at times an instantaneous current of over 1200 amperes to vaporize it, as was shown on one occasion by the opening of the main circuit breakers, set at 1800 amperes, when the total load was but 600 amperes.

The experimental investigation was begun with the apparatus connected as shown in the wiring diagram, Plate II. The current through the series coil was measured by means of a

Weston ammeter,(0-15), number 4088, the load being controlled by a lamp rack and carbon plate rheostat. A Weston voltmeter, (0-150), number 4405, was used to measure the drop over the armature, brushes, non-inductive resistance and compensating coils in series. A field rheostat in series with the pressure circuit offered a convenient and effective method of adjusting the pressure to any desired value, in most cases 107 volts. The meter was operated on a 125 volt storage battery circuit, while the auxiliary series field coils were connected through an asbestos lined fuse box direct to the 110 volt D.C. generator leads.

The initial readings, secured on Oct. 26, were obtained with magnets 8 and 2 in their places on the meter, #8 being to the left and #2 to the right, as shown in Plate III. It was recorded that opposite poles of the magnets were uppermost, but unfortunately not which was of north polarity. It may be assumed in the light of subsequent results, however, that their polarities were as indicated on Plate III. The first fuse blown was when the coils were in the position arbitrarily designated as 0^{0}, the flux tending to pass through the magnets in the direction indicated in Plate IV. An increase in speed of about 51% was noted. The second fuse blown was with the coils in the 90^{0} position,(see Plate IV), the result being an apparent decrease of 5% in the speed.Succeeding blows with the coils in the 0^{0} position produced only slight effect. The result of the first fuse blown at 180^{0} was an enormous increase in speed, 492%. The effect of subsequent blows may be noted by reference to the data and the curves plotted therefrom.

Considerable trouble was experienced after several such blows, the speed of the meter varying over a wide range. This is illustrated best by the series of readings taken on Nov. 5, 6, and 10, in each of which the speed gradually decreased from the start. The series on Nov. 6, especially, was taken with extreme care, the meter being thoroughly protected from all drafts and jars, and a note made of any disturbing influence which it proved impossible to avoid. The variation in speed continued, however, in spite of all precautions, which would indicate that the drag magnets, rendered very weak by the repeated violent magnetic blows to which they had been previously subjected, were gradually regaining their strength to a slight extent. The fact that the drag magnets were extremely weak was proved conclusively by the readings secured on Nov. 11, in which a 37.5% increase in power caused an increase in the speed of 111.0%, showing the magnets to be too weak to be of any use in their original capacity, viz., that of rendering the speed of the meter directly proportional to the power.

Beginning Nov. 14, the meter was operated somewhat differently, the pressure circuit being connected across the 125 volt storage battery and the series circuit being connected across two storage cells in series. This reduced the actual amount of power consumed, although manifestly the reading of the meter would be the same for similar currents and pressures in either case.

It was quite evident from readings taken on and previous to Nov. 17 that the repeated magnetic blows in the 0^{C}

position had practically brought the magnets to a condition of equilibrium, where such blows caused only small changes in speed. Accordingly, on Nov. 18, the direction of the magnetic blows was advanced through an angle of 90^0 each time, the succession being 0^0, 90^0, 180^0, 270^0, 0^0, etc. The effect of this, as may be easily seen from the curves, was to have each blow at 180^0 increase the speed, while each blow at 0^0 caused a decrease. Blows at 90^0 and 270^0, in which the axial plane of the momentary field was at right angles to the axial plane of the field from the permanent magnets, caused only slight changes in speed. A like series of readings on Nov. 19 gave similar results, and justify the conclusion that the magnets were alternately magnetized and demagnetized by the blows, according to the direction of the momentary fields.

In the next three series of readings, taken Nov. 20, 23, and 24, repeated magnetic blows were given with the coils in the 0^0 and 90^0 positions. It was found in these cases as formerly, that the effects of such blows were always very slight, and not constant in direction, showing that the magnets had practically reached a condition of equilibrium. Accordingly, magnets #8 and #2 were removed, #6 and #1 being substituted for them, their position and polarity being as shown in Plate III.

An examination of the resultant polarity of magnets #8 and #2, as illustrated by shadowgraphs #1 and #2, showed that the lower pole tips only were magnetized to any extent, the upper tips scarcely having sufficient strength to support a small needle, the other pole being now located in the upper

bend of the magnet. This suggested the desirability of securing some method of measuring the strength of each pole separately before and after each blow. It was at first attempted to do this by construsting an armature the exact size of the pole tip, and hanging from the center of this a very light basket. The armature was held by the magnetic attraction to the pole tip, and small shot were then poured carefully into the basket until sufficient weight had been added to cause the armature to pull away from the pole. This method was found, however, to give very inaccurate and widely varying results, as well as being extremely tedious, so it was finally abandoned.

The final method adopted was to take a shadowgraph of the field of each magnet both before and after every magnetic blow, and this proved the most satisfactory scheme of any. The shadowgraphs were obtained photographically, the magnets being removed from the meter after each blow and laid horizontally upon a table. A dry plate was then laid upon the magnet with its sensitive side uppermost, and iron filings scattered evenly upon it. After tapping the plate gently to cause the filings to arrange themselves in the direction of the field, an incandescent lamp was held a few feet above the plate and switched on for a couple of seconds. The white outlines of the magnets seen on the prints included were traced in later for convenience in reference.

The remainder of the data obtained should be self explanatory by referring to the tabulated data, curves, and shadowgraphs, as the results follow the same general trend as those previously obtained. The blows at 90° and 270° were

omitted in most cases, however, as it had been shown quite conclusively that the effect of a blow in either of these positions was comparitively small and of little significance. Two other pairs of magnets, in addition to those previously mentioned, were used, those designated by the numbers 5 and 7 having like poles of south polarity uppermost, while X and Z had unlike poles uppermost. Th initial condition of either of these pairs may be seen in outline by referring to Plate III, or in greater detail from the shadowgraphs of their fields.

Discussion of Results.

In the series of readings taken with magnets #8 and #2, the first point clearly proven is that the first effect of a magnetic blow in either the 180° or 0° position is to cause an increase in the speed, indicating a demagnetization of the drag magnets. The effect seemed to be larger in the 180° than in the 0° position. On account of unfortunately omitting to note the polarity of the magnets, any explanation of this inequality of effect becomes merely conjecture, although the readings obtained subsequently with other magnets would indicate,- reasoning by analogy,- that the polarity was as shown in Plate III. The second point shown clearly is that the effect of a blow at 90° or 270°, in which the axial plane of the momentary field is at right angles to the axial plane of the drag magnet's field, produces, in general, only a relatively slight effect on the speed, this effect varying so widely in magnitude and direction that there are grounds for supposing it to be due in part to the mechanical shock sustained by the meter during the blowing of the fuse. Third, it is shown that when the drag magnets have been subjected to repeated blows until very much weakened, a condition is finally reached in which blows in the 180° and 0° positions will alternately magnetize and demagnetize the magnets. It should be noted that the average demagnetization is slightly larger than the average magnetization, so that the resultant effect of a cycle of magnetic blows is a reduction in the strength of the magnets.

In the series of readings taken with magnets #1 and #6, in which like poles are uppermost, the first blows in what-

ever position caused an increase in the speed. The effect at 0^0 was greater than at 180^0, but the discrepancy between the two values was not nearly as great as in the previous case. As before, the effect of the blows steadily decreased in amount, showing that the magnets were gradually approaching the point of seeming equilibrium formerly commented upon. A peculiarity illustrated by the shadowgraphs numbers 3 and 4, taken at the close of this series, ought perhaps to be mentioned. That is, that while in magnet #6 the poles are located in the lower tip and the upper bend, in magnet #1 they are located in the upper tip and the upper bend.

The series of readings obtained with magnets #5 and #7 also had like magnet poles uppermost, and the results obtained do not differ materially from those of the preceding series. It is true that the blow in the 180^0 position caused a considerably larger increase in speed than that in the 0^0 position, but this might easily be explained by a difference in strength of the magnets. Here, as mentioned in discussing the previous series, the same peculiar distribution of the poles is noticed. This seems only to occur when the magnets have like poles uppermost at the start, but an adequate explanation is hard to find. The difficulty is increased by the fact that in the final series of readings- that using magnets X and Z- there occurs an instance in which the distribution of poles before the magnetic blow was identical with the distribution in the present series, but in which the location of the poles after blowing the fuse was different from in the present instance. The only hypothesis which seems reasonable is that the

strength of the various poles differed widely, even though the polarity was the same, an explanation which the data secured in this investigation offers no means of proving or disproving.

In the last series, taken with magnets X and Z, there were unlike poles uppermost, as shown by Plate III, or shadowgraphs 15 and 16. Blows were first given repeatedly in the 0^0 position, until the effect of such became very slight. One fuse was then blown with the coils in the 90^0 position, the result corroborating the statement previously made that the effect of a blow in this position was comparatively negligible. The blows were then alternated between the 0^0 and 180^0 positions until the condition of equilibrium was reached. The effect of the first blow in the 180^0 position was again considerably larger than that of the first blow at 0^0. One interesting feature of this run is brought out by the shadowgraphs, in which at times there are three or four poles clearly shown to exist in each magnet. For example, in shadowgraphs 25 and 26 three poles may be readily perceived, while in numbers 29, 30, and 34, four poles may be seen. Number 29 shows this most clearly. It should be noted, however, that two of these poles are extremely weak, while the other two are comparatively strong. The most plausible explanation of this phenomenon seems to be that the greater portion of the strong flux from the momentary field traverses the upper portion of the magnets, the eddy currents in the disc tending to oppose its passage through the lower portions. Accordingly, the upper arm of each magnet usually develops two poles under the action of the mo-

mentary field, while the lower arm, being acted upon less strongly, tends to retain its former polarity, although in a much weaker state. The effect is therefore much the same as if the drag magnet were subdivided into two other magnets, one of which is very weak. It should be pointed out, however, that under normal operating conditions the strong momentary field will originate beneath the drag magnets instead of above them, and the curvature of the magnets will not conform so closely to the curvature of the momentary fields, so that the effect might be slightly different, It is not probable, though, that the difference would be significant.

The size of the fuses blown in this investigation was purposely larger than those which would be used in connection with the meter under ordinary operating conditions; this was done to secure an absolutely unmistakeable effect. It is quite possible, and indeed more than probable, that by using a fuse in proportion with the capacity of the meter, it would have required the blowing of several fuses to have produced the same effect which was secured by a single one of the larger fuses, but there is no reason for believing that the direction of the effect would have been changed as well as the magnitude. The conclusions drawn from the results are therefore made general in their statement, without regard to the size of the fuse.

- CONCLUSIONS. -

I. The first effect of a powerful momentary field is to cause a demagnetization of the drag magnets, irrespective of the direction between the axial plane of such a field and that of the permanent magnets.

II. The demagnetizing effect of a momentary field is least when its axial plane is at right angles with the axial plane of the field of the permanent magnets.

III. The demagnetizing effect of a momentary field is greatest when its axial plane coincides with the axial plane of the field of the permanent magnets, the fluxes being opposed in direction.

IV. The effect of a momentary field may be to change either the number, location, intensity, or polarity of any or all the poles of the drag magnets, or any combination of these.

V. After the magnets have been subjected to repeated magnetic blows they tend to arrive at a condition of equilibrium, where further blows in any direction will cause a variation over only a certain limited range.

VI. The average effect of a cycle of magnetic blows is a reduction in the strength of the magnets; which reduction may be larger or smaller according to the proximity of the state of equilibrium above mentioned.

VII. There is no position of the field coils relative to the drag magnets which will of itself absolutely protect the latter from the influence of momentary fields produced by short circuits. The right angle relation between the axial planes of the fields is the most effective in this respect.

VIII. Assuming the right angle relation between the fields, it is preferable to have unlike poles of the drag magnets uppermost, as this reduces leakage between the magnets, and increases the effective flux passing through the disc.

EXPLANATION OF DATA AND CURVES.

The data is tabulated as experimentally obtained, each reading showing the time taken under the given conditions of current and pressure for a certain number of revolutions of the meter disc, usually 100. When the meter seemed to be running steadily, as indicated by a close agreement between several successive readings, the average of these readings was taken and used in subsequent computations. In some cases the speed of the meter required considerable time to become approximately constant: in many of these instances only such of the readings as were deemed significant were used in obtaining the average, and are indicated on the data sheets by bracketing. The effect of blowing the fuse, which in each case is of 50 amperes capacity, is preceded by a plus (+) or minus (-) sign, indicating an increase or a decrease in the speed, respectively.

The shadowgraphs for both magnets are mounted upon the same sheet in every case, that of the magnet which was located on the right hand of the meter, (See Plate III), being in all instances placed uppermost, and vice versa.

The curves plotted from point to point show the individual readings taken for each day's run, the time in minutes and seconds for 100 revolutions of the disc being the ordinates. Where the data records the time for any other number of revolutions, the results are reduced to the former basis before plotting. The instant of blowing each fuse is shown by a short vertical line starting from the hori-

zontal axis - the position of the blow being given just below. The straight line curve is plotted with ordinates showing the average speed of the meter disc in revolutions per second, the readings spanned by the horizontal portions of the curve being the ones used in computing the averages. Both curves are interrupted at points where for any reason the meter stopped running, as for example when a pause was made to take shadowgraphs of the magnets' fields.

EXPERIMENTAL

DATA.

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF FLOW IN R.P.S.	EFFECT OF FLOW IN %	REMARKS.
OCT 26		1	9.0	105	100	7	47.4					Using magnets #8 & #2; these are subsequently used until Nov. 24.
		2	"	"	"	7	47.2					
		3	"	"	"	7	47.0					
		4	"	"	"	7	48.4					
		5	"	"	"	7	48.2	4.6764	.2138			
	0^{o}	6	9.0	105	100	5	9.8					
		7	"	"	"	5	10.8					
		8	"	"	"	5	8.6					
		9	"	"	"	5	11.0	3.1005	.3225	+.1087	+50.9	
	90^{o}	10	9.0	105	100	5	29.6					
		11	"	"	"	5	26.6					
		12	"	"	"	5	26.1					
		13	"	"	"	5	22.2	3.2610	.3063	-.0162	- 5.02	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
OCT 27		1	9.0	107	100	4	51.0					
		2	"	"	"	4	52.2					
		3	"	"	"	4	51.2					
		4	"	"	"	4	52.0					
		5	"	"	"	4	52.6	2.9180	.3425			
	0°	6	9.0	107	100	4	34.2					
		7	"	"	"	4	35.0					
		8	"	"	"	4	34.6					
		9	"	"	"	4	36.2					
		10	"	"	"	4	35.4	2.7510	.3638	+.0213	+6.215	
	90°	11	9.0	107	100	4	37.0					Connector burned off;fuse wire remained intact.
		12	"	"	"	4	33.0					
		13	"	"	120	5	27.8					
		14	"	"	100	4	34.0					
		15	"	"	120	5	28.6	2.7420	.3642	+.0004	+.11	
	0°	16	9.0	107	100	4	20.6					
		17	"	"	"	4	20.8					
		18	"	"	"	4	19.2					
		19	"	"	"	4	19.2					
		20	"	"	"	4	20.0	2.6000	.3846	+.0204	+5.6	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 4		1	9.0	107	100	4	1.8					Released field coils.
		2	"	"	"	4	2.0					Readjusted field coils.
		3	"	"	"	4	2.6					
		4	"	"	"	4	1.2	2.4190	.4136			
	90°	5	9.0	107	100	4	15.4					
		6	"	"	"	4	13.8					
		7	"	"	"	4	13.6					
		8	"	"	"	4	15.6					
		9	"	"	"	4	16.6					
		10	"	"	"	4	17.8					
		11	"	"	"	4	16.4					Adjusted field coils.
		12	"	"	"	4	14.2					
		13	"	"	"	4	16.0	2.5550	.3918	-.0218	- 5.28	
	180°	14	9.0	107	200	1	26.2					
		15	"	"	"	1	26.0					
		16	"	"	"	1	26.2	.4306	2.3200	+1.9280	+492.0	
	270°	17	9.0	107	200	1	16.6					
		18	"	"	"	1	16.2					
		19	"	"	"	1	16.4	.3820	2.6180	+.2980	+12.85	
		20	9.0	107	200	2	49.4					Moved drag magnets out to reduce speed.
		21	"	"	"	2	48.2					
		22	"	"	"	2	50.0					
		23	"	"	"	2	50.8	.8480	1.1790			
	0°	24	9.0	107	200	3	0.0					Apparently weak blow.
		25	"	"	"	3	3.0					
		26	"	"	"	3	4.2					

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 4		27	9.0	107	200	3	3.4					
		28	"	"	"	3	4.4	.9150	1.0920	-.0870	-7.38	
	90°	29	9.0	107	200	3	3.0					
		30	"	"	"	3	5.0					
		31	"	"	"	3	4.0	.9200	1.0870	-.0050	- .458	
NOV 5		1	4.0	107	100	2	57.2					Moved magnets back to initial position.
		2	"	"	"	2	57.8					
		3	"	"	"	3	5.6					
		4	"	"	"	3	13.2					
		5	"	"	"	3	26.6					
		6	"	"	"	3	24.4					
		7	"	"	"	3	25.6					
		8	"	"	"	3	30.0					
		9	"	"	"	3	33.8					
		10	"	"	"	3	37.8					
		11	"	"	"	3	36.8					
		12	"	"	"	3	50.8					
		13	"	"	"	4	15.8					
		14	"	"	"	4	31.0					
		15	"	"	"	4	21.2					
		16	"	"	"	3	58.6					
		17	"	"	"	4	5.2					
		18	"	"	"	4	8.6					
		19	"	"	"	4	26.2					

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 6		1	4.0	107	100	2	26.6					
		2	"	"	"	2	27.2					
		3	"	"	"	2	21.8					
		4	"	"	"	2	29.0					
		5	"	"	"	2	37.2					
		6	"	"	"	2	36.6					
		7	"	"	"	2	36.6					
		8	"	"	"	2	40.0					
		9	"	"	"	2	47.2					
		10	"	"	"	2	53.2					
		11	"	"	"	2	55.6					
		12	"	"	"							Reading omi tted.
		13	"	"	"	3	0.2					
		14	"	"	"	3	0.6					
		15	"	"	"	3	1.4					
		16	"	"	"	3	5.6					
		17	"	"	"	3	13.0					
		18	"	"	"	3	10.8					
		19	"	"	"	3	12.0					
		20	"	"	"	3	16.6					
		21	"	"	"	3	15.6					
		22	"	"	"	3	14.6					
		23	"	"	"	3	11.2					
		24	"	"	"	3	12.8					Left room for 1 minute.
		25	"	"	"	3	20.6					
		26	"	"	"	3	21.6					
		27	"	"	"	3	21.8					Boy walked past twice.
		28	"	"	"	3	31.8					
		29	"	"	"	3	17.8					
		30	"	"	"	3	18.2					

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	REVS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 6		31	4.0	107	100	3	35.2					Man passed by.
		32	"	"	"	3	39.2					Blew on disc from 18 in.
		33	"	"	"	3	42.4					
		34	"	"	"	3	40.0					
		35	"	"	"	3	41.4					
		36	"	"	"	3	45.0					
		37	"	"	"	3	53.6					Adjusted coils to zero
		38	"	"	"	3	44.8					degrees and fastened.
		39	"	"	"	3	47.2					
		40	"	"	"	3	44.8					
		41	"	"	"	3	40.0					Adjusted ammeter and
		42	"	"	"	3	49.4					voltmeter slightly.
		43	"	"	"	3	52.2					
		44	"	"	"	3	55.6					
		45	"	"	"	3	55.0					
		46	"	"	"	3	56.2					
		47	"	"	"	4	9.0					

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 10		1	4.0	107	100	2	12.6					
		2	"	"	"	2	23.2					
		3	"	"	"	2	19.0					
		4	"	"	"	2	16.0					
		5	"	"	"	2	17.4					
		6	"	"	"	2	21.4					Adjusted field coils.
		7	"	"	"	2	26.8					
		8	"	"	"	2	29.0					
		9	"	"	"	2	37.8)					
		10	"	"	"	2	35.6)					
		11	"	"	"	2	37.8)					
		12	"	"	"	2	38.2)	1.5740	.6350			
	0°	13	4.0	107	100	3	45.4)					
		14	"	"	"	3	48.0)					
		15	"	"	"	3	52.6)					
		16	"	"	"	4	1.6)					
		17	"	"	"	3	54.0)	2.3240	.4300	-.2050	-32.3	
		18	"	"	"	4	4.2					
		19	"	"	"	4	1.0					Adjusted field coils.
		20	"	"	"	4	6.0					
		21	"	"	"	4	14.8					
		22	"	"	"	4	18.4					
		23	"	"	"	4	18.0					
		24	"	"	"	4	23.8					
		25	"	"	"	4	24.0					
		26	"	"	"	4	32.2					
		27	"	"	"	4	33.0					
		28	"	"	"	4	33.8					
		29	"	"	"	4	39.8					
		30	"	"	"	4	43.6					
		31	"	"	"	4	47.4					

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 11		1	4.0	107	100	5	18.2					
		2	"	"	"	5	18.2	3.1820	.3140			
		3	5.5	107	100	2	34.6					% increase of power = 37.5%
		4	"	"	"	2	30.4					
		5	"	"	"	2	29.4					
		6	"	"	"	2	31.6					
		7	"	"	"	2	28.2					
		8	"	"	"	2	30.4					
		9	"	"	"	2	31.8					
		10	"	"	"	2	30.2	1.5080	.6630			% increase of speed = 111.0%
NOV 13		1	4.5	107	100	3	4.2					
		2	"	"	"	3	4.0					Adjusted field coils.
		3	"	"	"	3	2.8					
		4	"	"	"	3	4.2					
		5	"	"	"	3	1.2					
		6	"	"	"	3	4.6					
		7	"	"	"	3	1.2	1.8317	.5460			
	90°	8	4.5	107	100	2	55.0					
		9	"	"	"	2	56.0					
		10	"	"	"	2	55.2					Adjusted field coils.
		11	"	"	"	3	2.2					
		12	"	"	"	3	0.6					
		13	"	"	"	3	1.2					
		14	"	"	"	3	1.0	1.7870	.5600	+.0140	+2.56	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 13	0^0	15	4.5	107	100	2	45.4					
		16	"	"	"	2	46.2					
		17	"	"	"	2	46.4					Adjusted field coils.
		18	"	"	"	2	48.8					
		19	"	"	"	2	53.2					
		20	"	"	"	2	51.8					
		21	"	"	"	2	52.4					
		22	"	"	"	2	53.0	1.6970	.5890	+.0290	+5.18	
	90^0	23	4.5	107	100	3	6.0					A rather violent blow.
		24	"	"	"	3	1.0					
		25	"	"	"	2	54.6					
		26	"	"	"	3	1.4					
		27	"	"	"	3	4.0					
		28	"	"	"	3	4.6					
		29	"	"	"	2	57.0					
		30	"	"	"	2	56.4	1.8060	.5540	-.0350	-5.93	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 17		1	4.5	117	100	2	43.8					On this and all subsequent days pressure coil is across storage battery, series coil on two storage cells in series.
		2	"	"	"	2	40.0					
		3	"	"	"	2	34.8					
		4	"	"	"	2	36.8					
		5	"	"	"	2	33.8					
		6	"	"	"	2	32.0					
		7	"	"	"	2	31.4					
		8	"	"	"	2	31.4					Adjusted field coils.
		9	"	"	"	2	31.6	1.5510	.6450			
	0^0	10	4.5	117	100	2	33.8					
		11	"	"	"	2	33.8					
		12	"	"	"	2	35.8					
		13	"	"	"	2	33.8					
		14	"	"	"	2	34.0					Adjusted field coils.
		15	"	"	"	2	31.6					
		16	"	"	"	2	33.2	1.5370	.6500	+.0050	+ .775	
	90^0	17	4.5	117	100	2	41.4					
		18	"	"	"	2	41.8					
		19	"	"	"	2	46.6					
		20	"	"	"	2	48.8					
		21	"	"	"	2	49.2					
		22	"	"	"	2	52.6					
		23	"	"	"	2	56.6					
		24	"	"	"	2	52.4					
		25	"	"	"	2	51.4					
		26	"	"	"	2	49.0					
		27	"	"	"	2	50.8	1.6910	.5910	-.0590	-9.08	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 18		1	4.5	107	100	3	14.4					
		2	"	"	"	3	16.6					E.M.F. fell .7 volt.
		3	"	"	"	3	9.6					
		4	"	"	"	3	14.0					
		5	"	"	"	3	14.4					
		6	"	"	"	3	14.6					
		7	"	"	"	3	14.6					
		8	"	"	"	3	14.8					
		9	"	"	"	3	14.6	1.9420	.5150			
	180°	10	4.5	107	100	1	58.0					
		11	"	"	"	2	1.0					
		12	"	"	"	1	58.2					
		13	"	"	"	2	4.8					
		14	"	"	"	2	6.2					Current .03 amp. low.
		15	"	"	"	2	2.0					
		16	"	"	"	1	59.2					
		17	"	"	"	2	1.2					
		18	"	"	"	2	2.4					
		19	"	"	"	2	0.2					
		20	"	"	"	2	3.6					
		21	"	"	"	2	4.4					
		22	"	"	"	2	1.8					Adjusted field coils.
		23	"	"	"	2	3.0					
		24	"	"	"	2	5.0					
		25	"	"	"	2	13.4					
		26	"	"	"	2	8.2					
		27	"	"	"	2	6.6					
		28	"	"	"	2	4.0					
		29	"	"	"	2	1.0					
		30	"	"	"	2	0.8					
		31	"	"	"	2	0.4	1.2300	.8130	+.2980	+57.9	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME.		AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
						MIN.	SECS.					
NOV 18	270°	32	4.5	107	100	1	54.0					
		33	"	"	"	1	49.2					
		34	"	"	"	1	46.0					
		35	"	"	"	1	46.6					
		36	"	"	"	1	49.6					
		37	"	"	"	1	51.2					
		38	"	"	"	1	52.0					Adjusted field coils.
		39	"	"	"	1	50.8	1.1000	.9090	+.0960	+11.8	
	0°	40	4.5	107	100	3	9.6					
		41	"	"	"	3	1.2					
		42	"	"	"	3	6.8					
		43	"	"	"	3	5.6					
		44	"	"	"	3	3.6					Adjusted field coils.
		45	"	"	"	3	8.2					
		46	"	"	"	3	8.4					
		47	"	"	"	3	5.6					
		48	"	"	"	3	5.4					
		49	"	"	"	3	2.0					
		50	"	"	"	3	4.2					
		51	"	"	"	3	2.0	1.8520	.5400	-.3690	-40.6	
	90°	52	4.5	107	100	2	55.0					
		53	"	"	"	2	57.4					
		54	"	"	"	3	0.0					
		55	"	"	"	2	57.4					
		56	"	"	"	2	57.6	1.7750	.5630	+.0230	+4.26	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 18	180°	57	4.5	107	100	1	53.2					
		58	"	"	"	1	52.8					
		59	"	"	"	1	55.0					
		60	"	"	"	1	53.0					
		61	"	"	"	1	48.0					
		62	"	"	"	1	45.2					
		63	"	"	"	1	46.2	1.1050	.9050	+.3420	+60.75	
NOV 19		1	4.5	107	100	2	12.0					
		2	"	"	"	2	12.2					
		3	"	"	"	2	8.0					
		4	"	"	"	1	57.4					
		5	"	"	"	1	58.6					
		6	"	"	"	1	58.0					
		7	"	"	"	1	58.8	1.2358	.8090			
	270°	8	4.5	107	100	1	47.0					Apparatus jarred by
		9	"	"	"	1	43.2					a motor's operation.
		10	"	"	"	1	47.2					
		11	"	"	"	1	47.0					Adjusted field coils.
		12	"	"	"	1	50.2					
		13	"	"	"	1	50.8					
		14	"	"	"	1	51.0	1.0806	.9250	+.1160	+14.33	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 19	0°	15	4.5	107	100	3	2.0					
		16	"	"	"	3	3.8					
		17	"	"	"	3	3.2					Adjusted field coils.
		18	"	"	"	3	2.4					
		19	"	"	"	3	2.0	1.8268	.5475	-.3775	-40.8	
	90°	20	4.5	107	100	2	57.0					
		21	"	"	"	3	4.0					
		22	"	"	"	3	11.4					150 H.P. motor started.
		23	"	"	"	2	57.0					
		24	"	"	"	3	1.6					Adjusted field coils.
		25	"	"	"	2	46.8					
		26	"	"	"	2	43.4					
		27	"	"	"	2	42.6					
		28	"	"	"	2	51.0					Motor stopped running.
		29	"	"	"	2	55.6					
		30	"	"	"	2	55.6					
		31	"	"	"	2	56.6	1.7522	.5705	+.0230	+4.2	
	180°	32	4.5	107	100	1	49.2					
		33	"	"	"	1	49.8					
		34	"	"	"	1	50.8					
		35	"	"	"	1	51.2					
		36	"	"	"	1	50.6	1.1032	.9060	+.3355	+58.8	
		37	4.5	107	100	1	44.0					
		38	"	"	"	1	44.8					
		39	"	"	"	1	46.2					
		40	"	"	"	1	46.2					
		41	"	"	"	1	46.4	1.0552	.9480			

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 19	270°	42	4.5	107	100	1	44.6					
		43	"	"	"	1	45.0					Adjusted field coils.
		44	"	"	"	1	47.0					
		45	"	"	"	1	51.8					
		46	"	"	"	1	54.8	1.0864	.9205	-.0205	-2.16	
		47	4.5	107	100	2	1.2					
		48	"	"	"	2	9.0					
		49	"	"	"	2	5.6					
		50	"	"	"	2	11.0					
		51	"	"	"	2	15.4					
		52	"	"	"	2	12.0					
		53	"	"	"	2	15.6	1.3350	.7490			
	0°	54	4.5	107	100	3	32.6					
		55	"	"	"	3	35.0					
		56	"	"	"	3	35.4	2.1433	.4665	-.2825	-37.7	
NOV 20		1	6.0	107	100	2	23.0					
		2	"	"	"	2	23.8					
		3	"	"	"	2	21.0					
		4	"	"	"	2	26.2					
		5	"	"	"	2	26.0					
		6	"	"	"	2	28.6					
		7	"	"	"	2	28.8					
		8	"	"	"	2	27.0	1.4728	.6790			

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 20	90°	9	6.0	107	100	2	16.0					
		10	"	"	"	2	13.4					Voltage rose .8 volt.
		11	"	"	"	2	18.0					Adjusted field coils.
		12	"	"	"	2	18.4					E.M.F. fluctuated.
		13	"	"	"	2	13.0					
		14	"	"	"	2	13.8					
		15	"	"	"	2	18.0					
		16	"	"	"	2	15.0					
		17	"	"	"	2	16.6					
		18	"	"	"	2	15.8	1.3580	.7360	+.0570	+8.4	
	0°	19	6.0	107	100	2	23.0					E.M.F. fluctuated.
		20	"	"	"	2	26.0					
		21	"	"	"	2	30.4					
		22	"	"	"	2	25.0					
		23	"	"	"	2	26.2					
		24	"	"	"	2	27.0	1.4627	.6840	-.0520	-7.05	E.M.F. varied slightly.
	90°	25	6.0	107	100	2	39.2					
		26	"	"	"	2	41.0					
		27	"	"	"	2	40.2					
		28	"	"	"	2	40.6	1.6025	.6240	-.0600	-8.77	

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF FLOW IN R.P.S.	EFFECT OF FLOW IN %	REMARKS.
NOV 23		1	6.0	107	100	2	4.0					
		2	"	"	"	2	0.2					Shook meter.
		3	"	"	"	2	0.8					
		4	"	"	"	2	1.6					
		5	"	"	"	2	0.4					
		6	"	"	"	2	1.0	1.2133	.8240			
	0°	7	6.0	107	100	1	54.8					
		8	"	"	"	1	55.0					
		9	"	"	"	1	55.0					Adjusted field coils.
		10	"	"	"	1	50.6					
		11	"	"	"	1	51.0					
		12	"	"	"	1	52.6					
		13	"	"	"	1	53.6					
		14	"	"	"	1	53.8					
		15	"	"	"	1	53.2	1.1329	.8830	+.0590	+7.15	
	90°	16	6.0	107	100	2	0.0					
		17	"	"	"	2	1.6					
		18	"	"	"	2	1.8					Adjusted field coils.
		19	"	"	"	2	1.6					
		20	"	"	"	2	1.2	1.2124	.8250	-.0580	-6.57	
	0°	21	6.0	107	100	1	58.0					
		22	"	"	"	1	58.8					
		23	"	"	"	1	59.6					
		24	"	"	"	1	59.0					Adjusted field coils.
		25	"	"	"	1	58.6					
		26	"	"	"	1	59.2	1.1887	.8415	+.0165	+2.00	

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 23	90°	27	6.0	107	100	2	3.8					
		28	"	"	"	2	4.0					Adjusted field coils.
		29	"	"	"	2	5.2					
		30	"	"	"	2	7.0					
		31	"	"	"	2	15.2					Change occurred during
		32	"	"	"	2	13.8					run.
		33	"	"	"	2	12.4					Shook meter again.
		34	"	"	"	2	12.2					
		35	"	"	"	2	13.6	1.2969	.7710	-.0705	-8.38	
	0°	36	6.0	107	100	2	9.4					Circuit breakers opened. (1800 amps.)
		37	"	"	"	2	17.0					Meter jarred.
		38	"	"	"	2	16.0					
		39	"	"	"	2	17.6					Adjusted field coils.
		40	"	"	"	2	21.2					
		41	"	"	"	2	15.6					
		42	"	"	"	2	26.2	1.3757	.7270	-.0440	-5.70	
NOV 24		1	6.0	107	100	1	59.8					
		2	"	"	"	1	58.8					
		3	"	"	"	1	59.8					
		4	"	"	"	2	5.8					
		5	"	"	"	2	5.6					
		6	"	"	"	2	5.2	1.2250	.8160			

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
NOV 24	90°	7	6.0	107	100	2	12.6					
		8	"	"	"	2	19.0					
		9	"	"	"	2	19.2					
		10	"	"	"	2	21.4					
		11	"	"	"	2	19.6	1.3836	.7230	-.0930	-11.4	
	0°	12	6.0	107	100	2	19.2					
		13	"	"	"	2	24.4					
		14	"	"	"	2	29.8					
		15	"	"	"	2	33.8					
		16	"	"	"	2	33.4					
		17	"	"	"	2	30.0	1.4843	.6740	-.0460	-6.35	Removed magnets #8 & #2, and shadowgraphed fields, see numbers 1 and 2. These magnets have been used entirely up to date.
DEC 1		1	9.0	107	40	2	53.5					Using magnets 1 and 6, N pole of each uppermost. #6 to the right, #1 to the left.
		2	"	"	"	2	53.0					
		3	"	"	"	2	54.0					
		4	"	"	"	2	53.0	4.3340	.2306			
	0°	5	9.0	107	100	3	2.2					
		6	"	"	"	3	0.8					
		7	"	"	"	3	3.2					
		8	"	"	"	3	3.8					
		9	"	"	"	3	2.6	1.8252	.5480	+.3174	+137.8	

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV..	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
DEC 1	180°	10	9.0	107	100	1	23.0					
		11	"	"	"	1	23.4					
		12	"	"	"	1	22.8	.8307	1.2040	+.4760	+87.00	
		15	7.0	107	100	2	5.4					
		16	"	"	"	2	4.4					
		17	"	"	"	2	5.4	1.2507	.8000			
	0°	18	7.0	107	100	1	29.6					
		19	"	"	"	1	35.8					
		20	"	"	"	1	36.0					
		21	"	"	"	1	38.0					
		22	"	"	"	1	37.0					
		23	"	"	"	1	38.2					
		24	"	"	"	1	38.4					
		25	"	"	"	1	38.8	.9622	1.0400	+.2400	+30.00	
	180°	26	7.0	107	100	1	33.2					
		27	"	"	"	1	33.0	.9310	1.0740	+.0340	+3.27	
		28	7.0	107	100	1	37.2					
		29	"	"	"	1	37.0					
		30	"	"	"	1	38.0					
		31	"	"	"	1	37.8	.9750	1.0250			
	0°	32	7.0	107	100	1	28.4					
		33	"	"	"	1	29.2					Removed magnets 1 & 6.
		34	"	"	"	1	29.2					shadowgraphed fields
		35	"	"	"	1	29.2	.8900	1.1240	+.0990	+9.65	numbers 3 and 4.

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF FLOW IN R.P.S.	EFFECT OF FLOW IN %	REMARKS.
DEC 3		1	9.0	107	100	3	54.6					Using magnets 5 and 7, S pole of each uppermost. #7 to right, #5 to left. See shadowgraphs numbers 5 and 6.
		2	"	"	"	3	55.2					
		3	"	"	"	3	54.8	2.3487	.4260			
	0°	4	9.0	107	100	2	48.0					
		5	"	"	"	2	47.4					
		6	"	"	"	2	49.0	1.6813	.5950	+.1690	+39.7	Shadowgraphed fields, numbers 7 and 8.
DEC 4		1	9.0	107	100	2	45.0					Using magnets 5 and 7.
		2	"	"	"	2	41.6					
		3	"	"	"	2	43.8					
		4	"	"	"	2	45.4					
		5	"	"	"	2	47.0					
		6	"	"	"	2	46.8					
		7	"	"	"	2	47.2					
		8	"	"	"	2	47.0	1.6547	.6050			
	180°	9	9.0	107	100	0	48.4					
		10	"	"	"	0	48.8					
		11	"	"	"	0	49.4					
		12	"	"	"	0	50.0					
		13	"	"	"	0	50.6					
		14	"	"	"	0	51.8					
		15	"	"	"	0	51.0					
		16	"	"	"	0	50.8					
		17	"	"	"	0	51.0					
		18	"	"	"	0	51.6	.5034	1.9880	+1.3830	+228.8	Shadowgraphed fields, numbers 9 and 10.

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF FLOW IN R.P.S.	EFFECT OF FLOW IN %	REMARKS.
DEC 4		19	6.0	107	100	1	32.6					Using magnets 5 and 7.
		20	"	"	"	1	33.6					
		21	"	"	"	1	31.6					
		22	"	"	"	1	34.6					
		23	"	"	"	1	35.6					
		24	"	"	"	1	34.0					
		25	"	"	"	1	37.8					
		26	"	"	"	1	39.4					
		27	"	"	"	1	41.6					
		28	"	"	"	1	40.0					
		29	"	"	"	1	41.6					
		30	"	"	"	1	46.0					
		31	"	"	"	1	44.4					
		32	"	"	"	1	44.0					
		33	"	"	"	1	44.4					
		34	"	"	"	1	54.4					
		35	"	"	"	1	56.4					
		36	"	"	"	1	58.2					
		37	"	"	"	1	54.4					Interim of 30 minutes, meter continued to run.
		38	"	"	"	2	13.2					
		39	"	"	"	2	19.0					
		40	"	"	"	2	17.6					
		41	"	"	"	2	17.4					
		42	"	"	"	2	26.8					
		43	"	"	"	2	5.8					
		44	"	"	"	1	55.6					Battery circuit opened.
		45	"	"	"	1	31.0					
		46	"	"	"	1	24.2					
		47	"	"	"	1	33.2					

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
DEC 4		48	6.0	107	100	1	31.0					Using magnets 5 and 7.
		49	"	"	"	1	37.0					
		50	"	"	"	1	44.0					
		51	"	"	"	1	31.0					
		52	"	"	"	1	27.0)					
		53	"	"	"	1	25.4)					
		54	"	"	"	1	26.4)					
		55	"	"	"	1	25.6)	.8610	1.1610			
	0^{o}	56	6.0	107	100	2	4.2					Opened breakers set at
		57	"	"	"	2	4.0					1800 amps.. load but 1100.
		58	"	"	"	2	6.0					
		59	"	"	"	2	5.2	1.2485	.8010	-.3600	-31.00	Shadowgraphed fields, numbers 11 and 12.
DEC 7		1	11.0	107	25	2	5.2					Using magnets X and Z,
		2	"	"	"	2	5.4					X to left; Z to right, see
		3	"	"	"	2	5.0					shadowgraphs 15 and 16.
		4	"	"	"	2	5.0	5.0060	.1998			
	0^{o}	5	11.0	107	50	3	3.6					
		6	"	"	"	3	3.4					
		7	"	"	"	3	3.0					
		8	"	"	"	3	3.4	3.6670	.2725	+.0727	+36.4	Shadowgraphed fields, numbers 17 and 18.

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
DEC 8		1	11.0	107	50	3	8.6					Using magnets X and Z.
		2	"	"	"	3	4.8					
		3	"	"	"	3	3.6					
		4	"	"	"	2	59.2					
		5	"	"	"	2	59.0					
		6	"	"	"	2	58.0					
		7	"	"	"	2	57.0					
		8	"	"	"	2	56.8					
		9	"	"	"	2	55.6					
		10	"	"	"	2	59.4					
		11	"	"	"	2	59.0					
		12	"	"	"	2	58.8	3.5996	.2778			
	0°	13	11.0	107	50	2	42.6					
		14	"	"	"	2	47.6					
		15	"	"	"	2	49.0					
		16	"	"	"	2	49.6					
		17	"	"	"	2	46.0					
		18	"	"	"	2	45.6	3.3346	.3000	+.0222	+8.0	Shadowgraphed fields, numbers 19 and 20.
		19	11.0	107	50	2	42.4					Magnets X and Z replaced.
		20	"	"	"	2	43.6					
		21	"	"	"	2	45.8					
		22	"	"	"	2	46.2					
		23	"	"	"	2	44.2					
		24	"	"	"	2	44.8					
		25	"	"	"	2	45.2					
		26	"	"	"	2	45.8	3.2950	.3035			

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
DEC 8	0°	27	11.0	107	50	2	37.4					
		28	"	"	"	2	39.0					
		29	"	"	"	2	39.2					
		30	"	"	"	2	38.0					
		31	"	"	"	2	37.6	3.1648	.3160	+.0125	+4.12	Shadowgraphed fields, numbers 21 and 22.
		32	11.0	107	50	2	38.6					Magnets X and Z replaced.
		33	"	"	"	2	37.2					
		34	"	"	"	2	36.2					
		35	"	"	"	2	36.0					
		36	"	"	"	2	36.6	3.1384	.3187			
	90°	37	11.0	107	50	2	37.4					Circuit breakers opened. (1800 amps.)
		38	"	"	"	2	37.0					
		39	"	"	"	2	36.8	3.1414	.3185	-.00025	-.078	Shadowgraphed fields. numbers 23 and 24.
DEC 9		1	11.0	107	50	2	45.8					Magnets X and Z replaced.
		2	"	"	"	2	44.0					
		3	"	"	"	2	45.0					
		4	"	"	"	2	45.8					
		5	"	"	"	2	46.0					
		6	"	"	"	2	46.2	3.3094	.3020			

DATE.	POSITION OF BLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME.		AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF BLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
						MI.	SECS.					
DEC 9	180°	7	11.0	107	100	2	18.2					
		8	"	"	"	2	18.0					
		9	"	"	"	2	18.6					
		10	"	"	"	2	18.8	1.3840	.7220	+.4200	+139.0	Shadowgraphed fields, numbers 25 and 26.
		11	11.0	107	100	2	7.0					Magnets X & Z replaced.
		12	"	"	"	2	6.6					
		13	"	"	"	2	6.6					
		14	"	"	"	2	7.2	1.2685	.7880			
	0°	15	11.0	107	100	2	19.2					
		16	"	"	"	2	18.4					
		17	"	"	"	2	18.2					
		18	"	"	"	2	19.0	1.3870	.7210	-.0670	-8.5	Shadowgraphed fields, numbers 27 and 28.
		19	11.0	107	100	2	21.0					Magnets X and Z replaced.
		20	"	"	"	2	21.6					
		21	"	"	"	2	20.6					
		22	"	"	"	2	21.4	1.4115	.7085			
	180°	23	11.0	107	100	1	39.6					
		24	"	"	"	1	39.0					
		25	"	"	"	1	38.6					
		26	"	"	"	1	38.8					
		27	"	"	"	1	39.2	.9904	1.0100	+.3015	+42.5	Shadowgraphed fields, numbers 29 and 30.

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF FLOW IN R.P.S.	EFFECT OF BLOW IN %	REMARKS.
DEC 10		1	6.0	107	100	1	53.8					Using magnets 5 and 7, #5 to left, #7 to right.
		2	"	"	"	1	54.0					
		3	"	"	"	1	53.8					
		4	"	"	"	1	54.0	1.1390	.8780			
	180°	5	6.0	107	100	1	9.6					
		6	"	"	"	1	9.6					
		7	"	"	"	1	9.8					
		8	"	"	"	1	9.6	.6965	1.4340	+.5560	+66.3	Shadowgraphed fields, numbers 13 and 14.
		9	9.0	107	100	1	49.2					Using magnets X and Z, X to left, Z to right.
		10	"	"	"	1	49.8					
		11	"	"	"	1	51.0					
		12	"	"	"	1	50.6					
		13	"	"	"	1	49.0					I slightly high.
		14	"	"	"	1	47.6					
		15	"	"	"	1	49.0					
		16	"	"	"	1	48.8					
		17	"	"	"	1	49.2	1.0935	.9140			
	0°	18	9.0	107	100	2	12.6					
		19	"	"	"	2	12.4					
		20	"	"	"	2	12.6					
		21	"	"	"	2	12.8	1.3260	.7540	-.1600	-17.5	Shadowgraphed fields, numbers 31 and 32.

DATE.	POSITION OF FLOW.	NUMBER.	AMPS.	VOLTS.	REVS.	TIME. MIN.	TIME. SECS.	AV. TIME PER REV.	AV. SPEED IN R.P.S.	EFFECT OF FLOW IN R.P.S.	EFFECT OF FLOW IN %	REMARKS.
DEC 11		1	9.0	107	100	2	20.8					Using magnets X and Z, X to left, Z to right, see shadowgraph no.33.
		2	"	"	"	2	23.6					
		3	"	"	"	2	22.8					
		4	"	"	"	2	22.4					
		5	"	"	"	2	22.0	1.4232	.7025			
	180°	6	9.0	107	100	2	0.0					
		7	"	"	"	2	0.4					
		8	"	"	"	2	0.6					
		9	"	"	"	2	1.0	1.2050	.8500	+.1275	+18.15	Shadowgraphed fields, see nos. 34, 35, & 36. Number 34 is a combination of the other two.

- MISCELLANEOUS DATA. -

When meter is stationary.

P.D. over meter	= 107 volts.
P.D. over commutator lead	= 0 volts.
P.D. over resistance coil	= 65 volts.
P.D. over compensating coil	= 12 volts.
P.D. over armature	= 30 volts.
Current in pressure circuit	= .04 amperes.

Therefore, approximately,

Resistance of resistance coil $= \frac{65}{.04}$ = 1625 ohms.

Resistance of compensating coil = 300 ohms.

****

Distance between upper poles of magnets when in place on the meter = 3/4 inch.

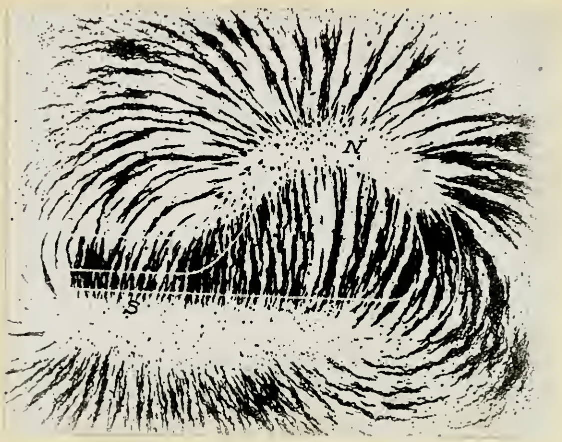
Gap between poles of magnet

X = 3.0 millimeters.	6 = 3.0 millimeters.
Z = 2.3 millimeters.	1 = 3.0 millimeters.
5 = 3.0 millimeters.	8 = 3.0 millimeters.
7 = 2.9 millimeters.	2 = 3.0 millimeters.

****

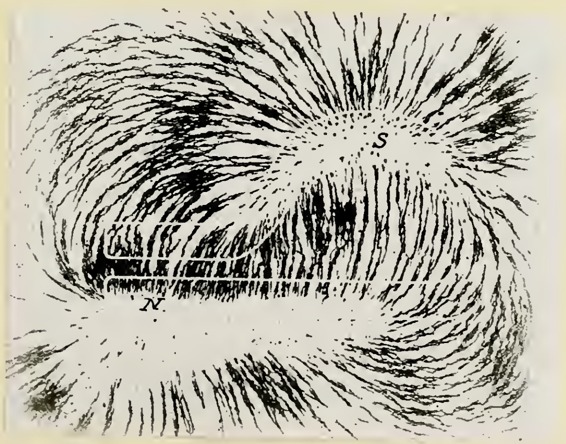
Length of fuse wire between contacts = 3.0 inches.

- SHADOWGRAPHS -



1

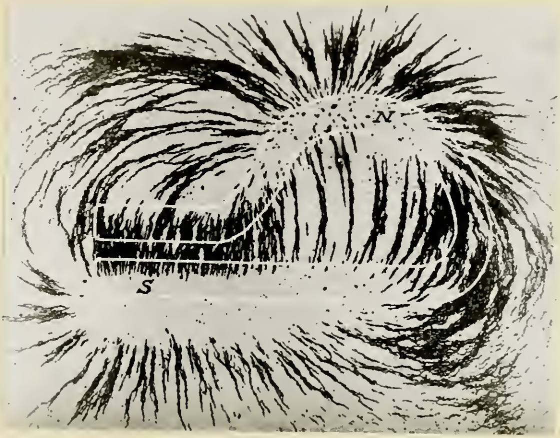
Magnet 2 Data Sheet 34.



2

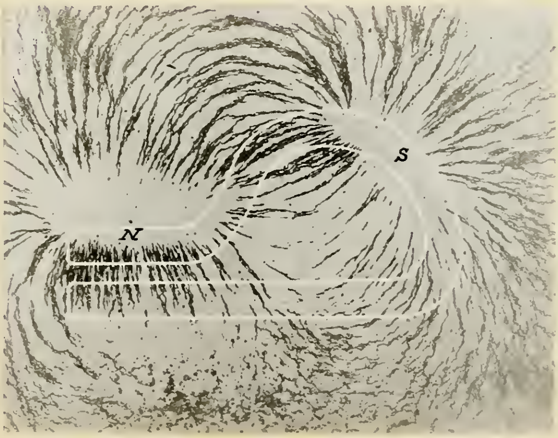
Magnet 8 Data Sheet 34.

ARMOUR
INSTITUTE OF TECHNOLOGY



Magnet 6. Data Sheet 35.

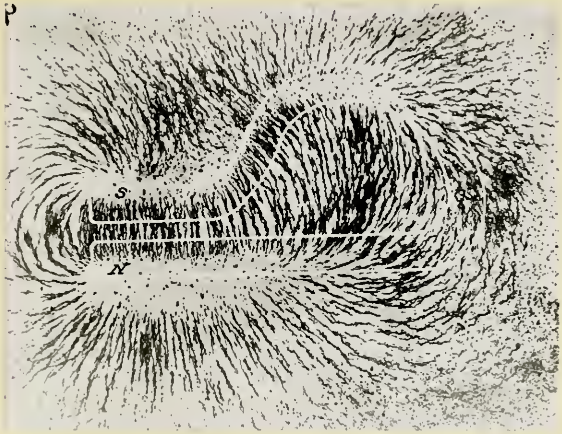
3



Magnet 1. Data Sheet 35.

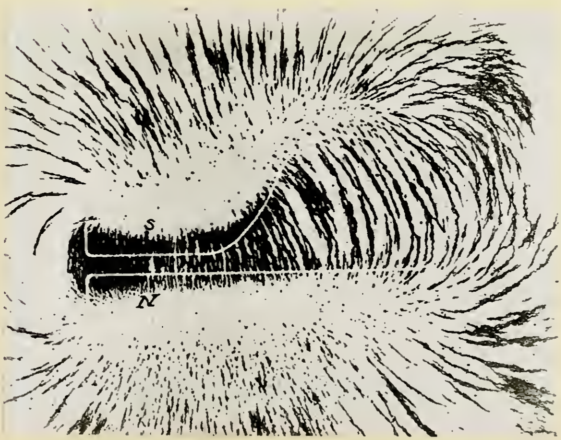
4

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



5

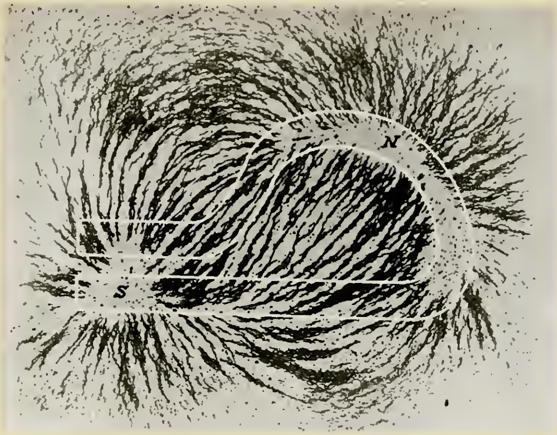
Magnet 7 Data Sheet 36.



6

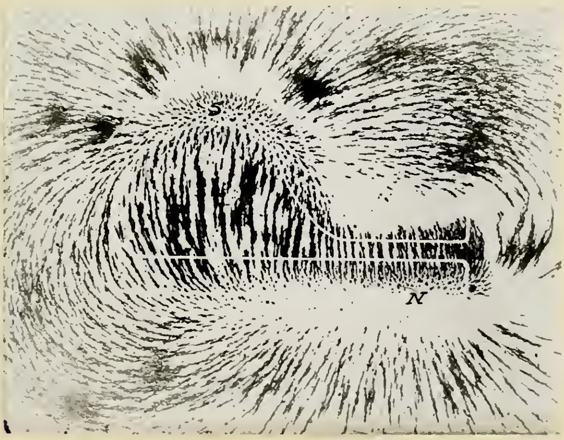
Magnet 5 Data Sheet 36.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



7

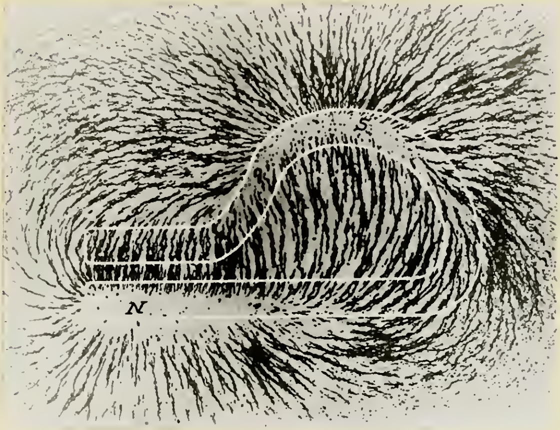
Magnet 7. Data Sheet 36.



8

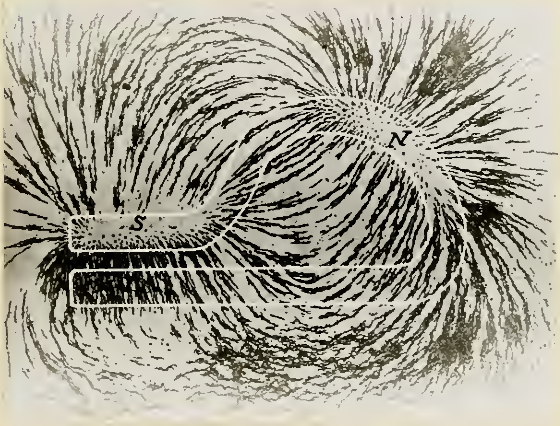
Magnet 5. Data Sheet 36.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



9

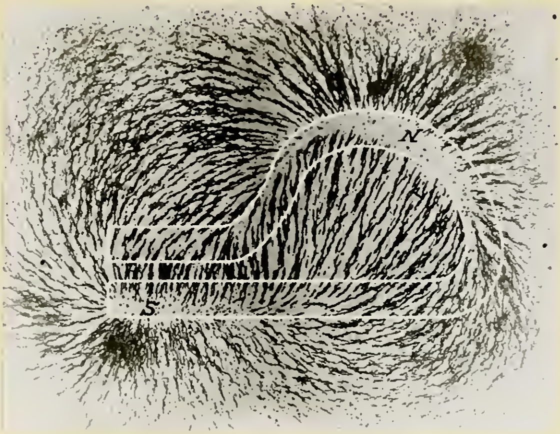
Magnet 7 Data Sheet 36.



10

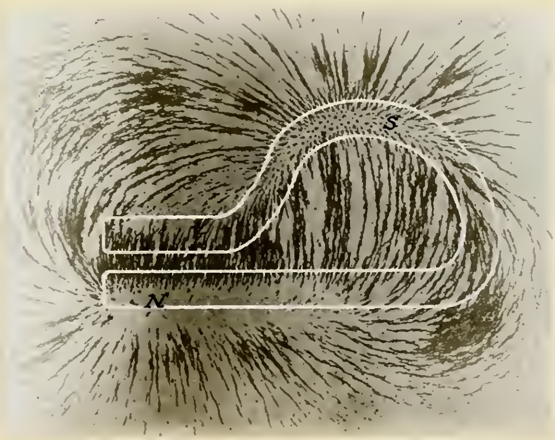
Magnet 5 Data Sheet 36.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



11

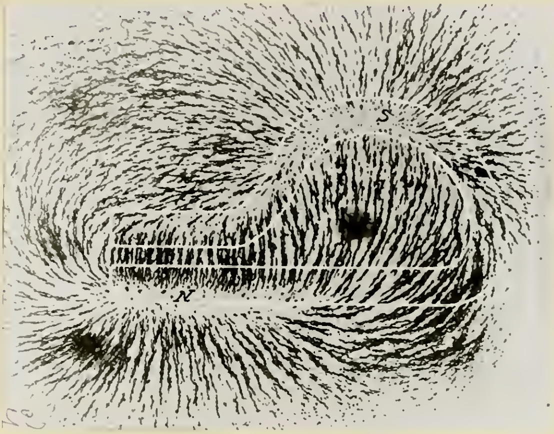
Magnet 7 Data Sheet 38.



12

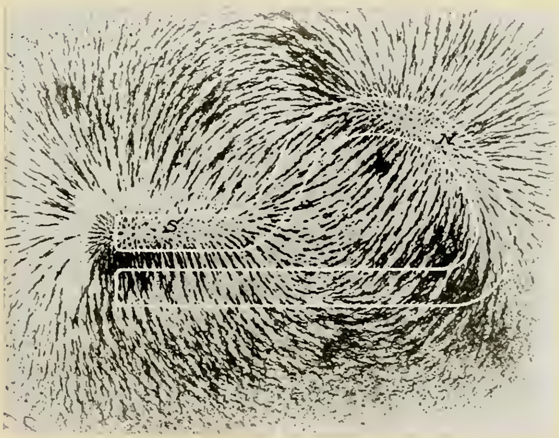
Magnet 5 Data Sheet 38.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



(13)

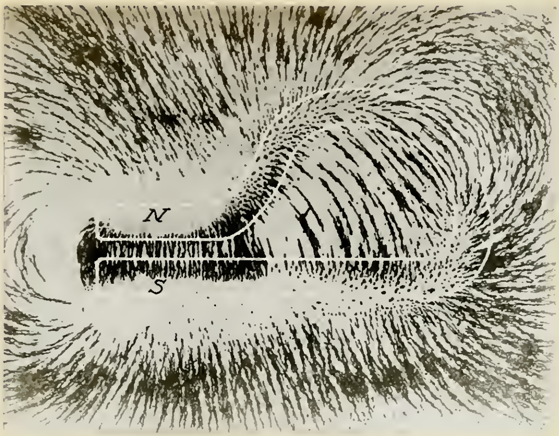
Magnet 7 Data Sheet 42.



(14)

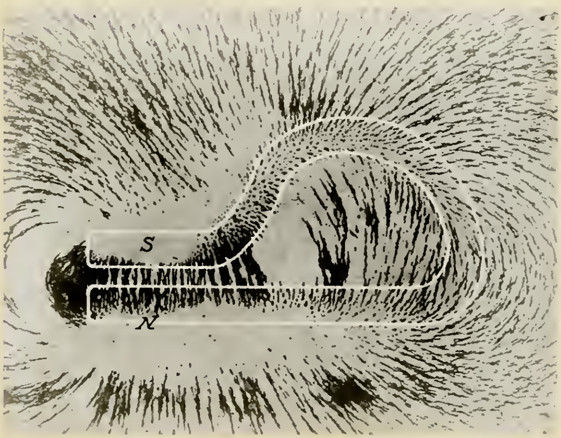
Magnet 5 Data Sheet 42.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



15

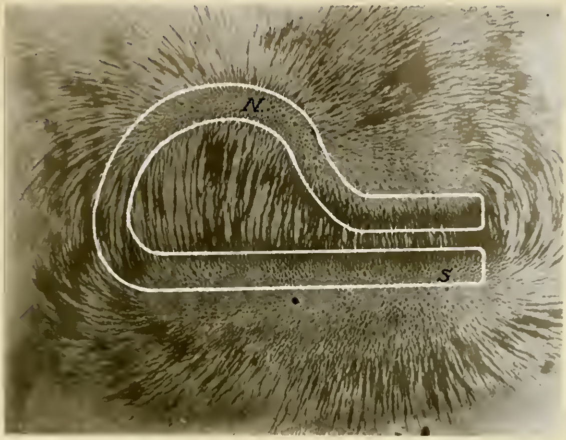
Magnet Z　　Data Sheet 38



16

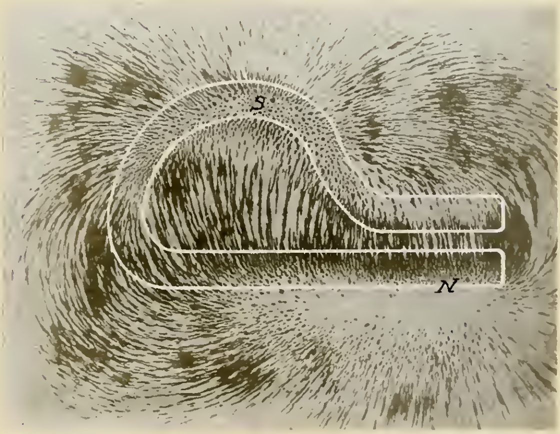
Magnet X　　Data Sheet 38.

[illegible]
[illegible]
[illegible]



17

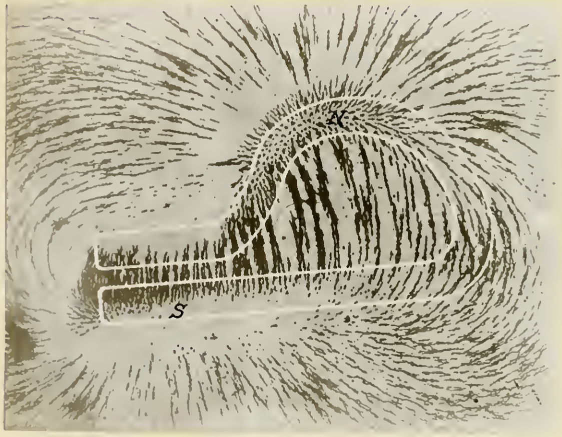
Magnet Z Data Sheet 38.



18

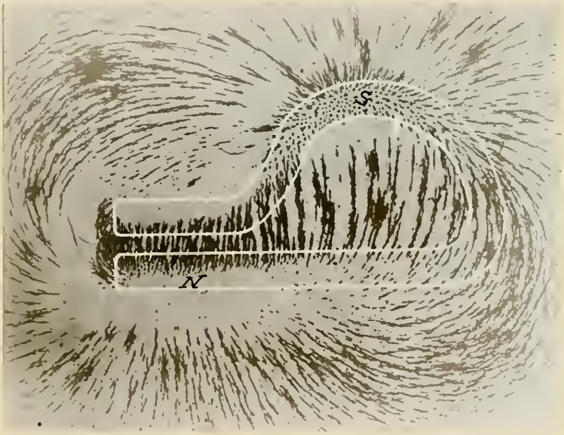
Magnet X Data Sheet 38.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



19

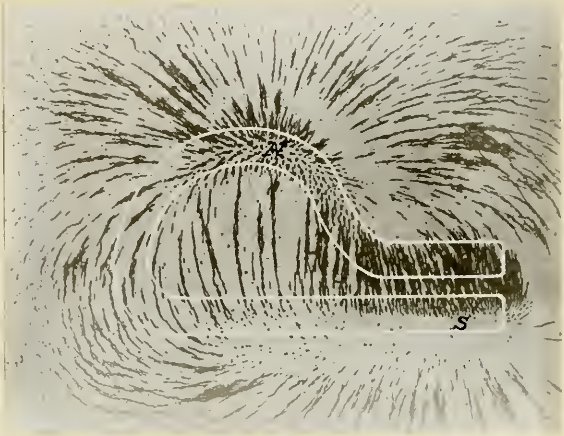
Magnet Z Data Sheet 39.



20

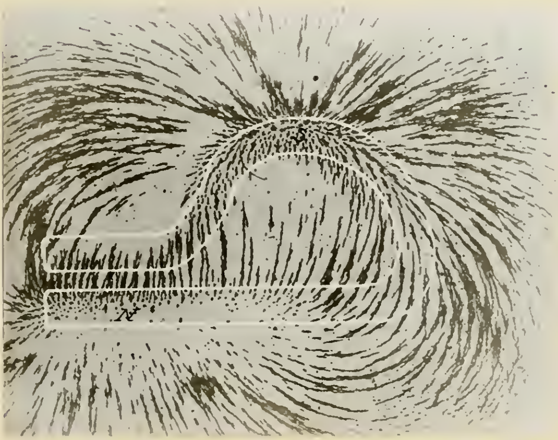
Magnet X Data Sheet 39.

INSTITUTE OF TECHNOLOGY
LIBRARY



21

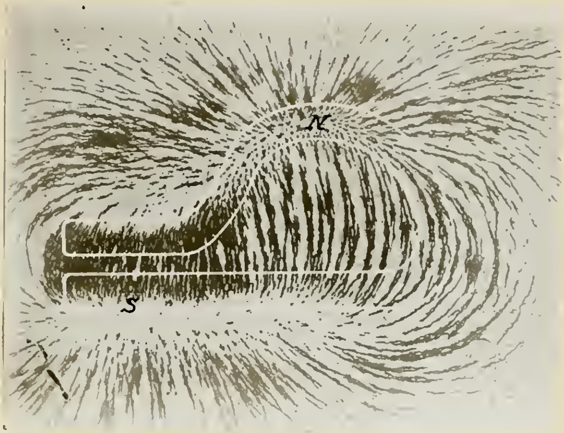
Magnet Z Data Sheet 40.



22

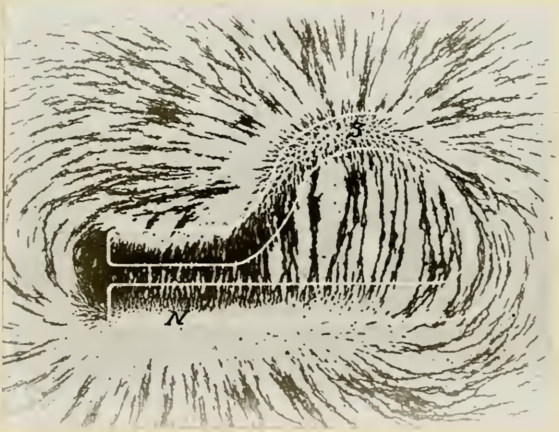
Magnet X Data Sheet 40.

ARMOUR
INSTITUTE OF TECHNOLOGY
[illegible]



23

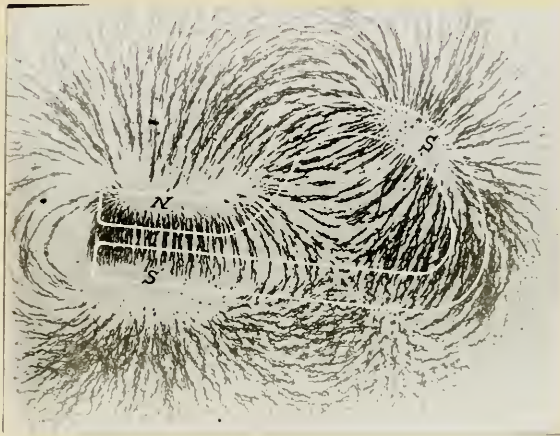
Magnet Z Data Sheet 40.



24

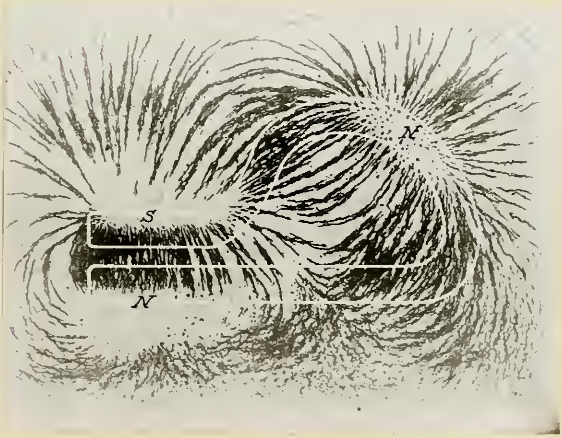
Magnet X Data Sheet 40.

ARMOUR
[illegible]
[illegible]



(25)

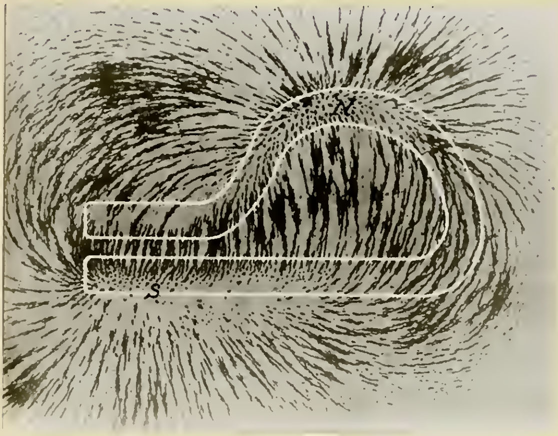
Magnet Z   Data Sheet 41



(26)

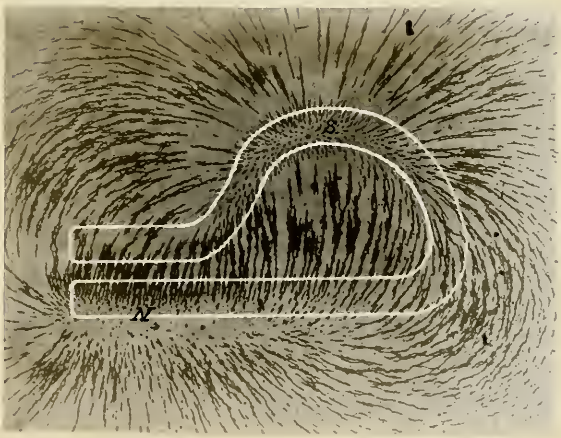
Magnet X   Data Sheet 41

ARMOUR
INSTITUTE OF TECHNOLOGY
[illegible]



(27)

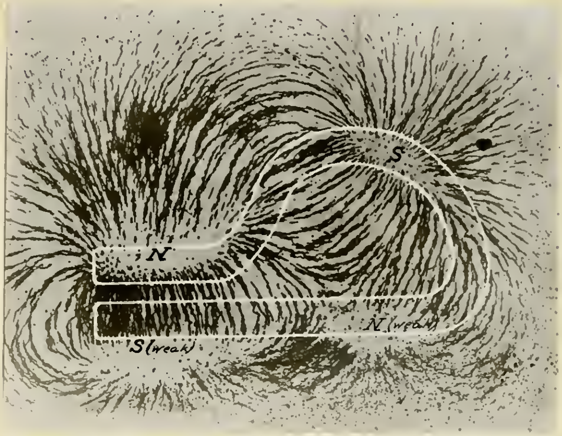
Magnet Z   Data Sheet 41



(28)

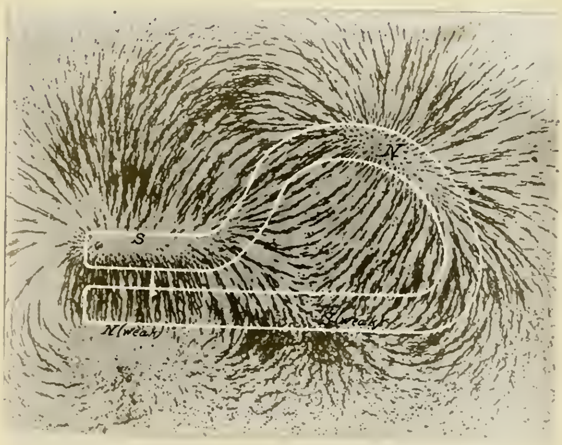
Magnet X   Data Sheet 41.

[illegible]
[illegible]
[illegible]



29

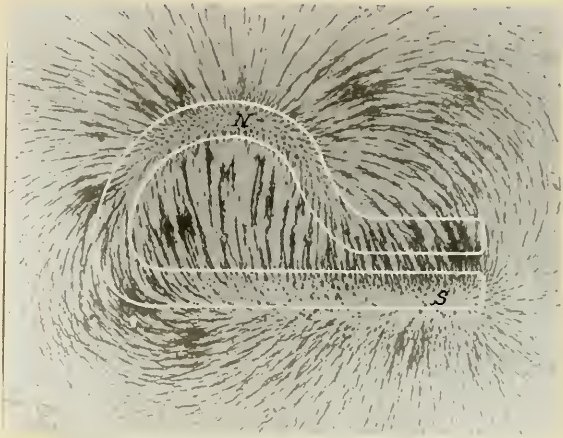
Magnet Z   Data Sheet 41



30.

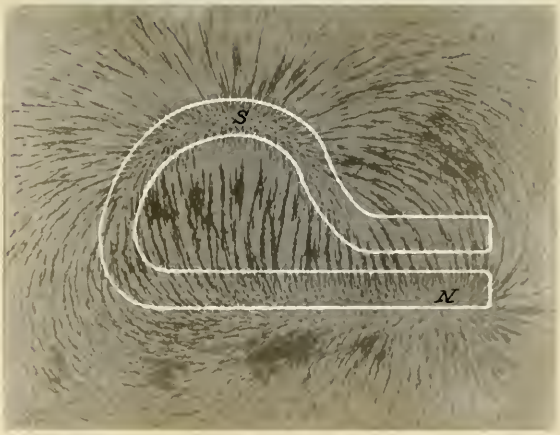
Magnet X   Data Sheet 41.

[illegible]
[illegible]
[illegible]



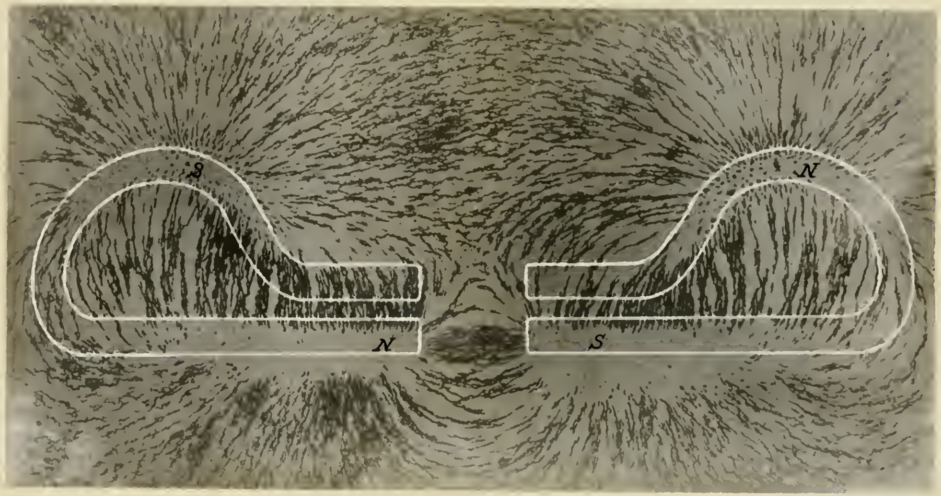
31

Magnet Z Data Sheet 42



32

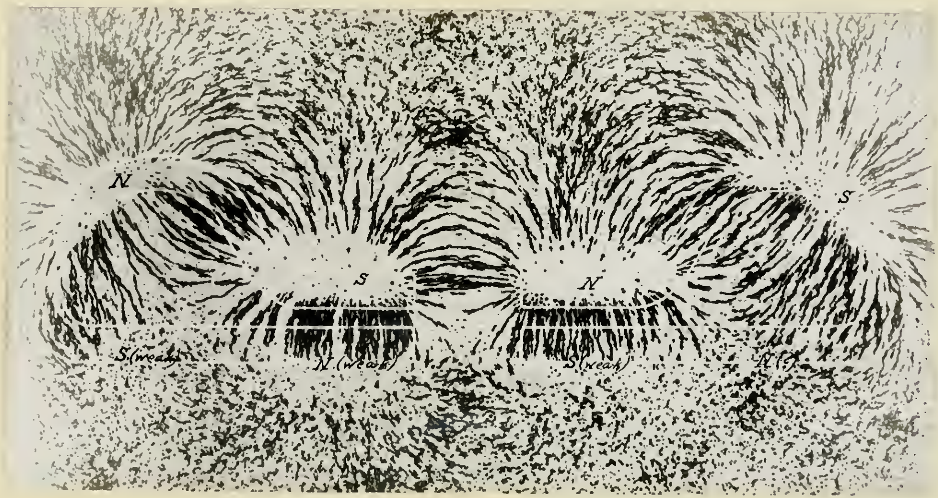
Magnet X Data Sheet 42.



Magnets X & Z

Data Sheet 43.

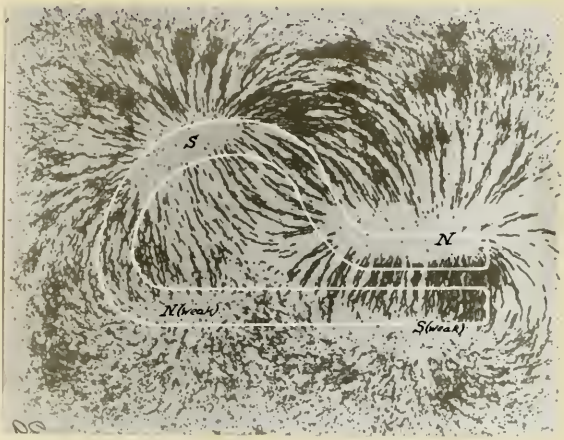
ARNOLD
[illegible]
LIBRARY



Magnets X & Z

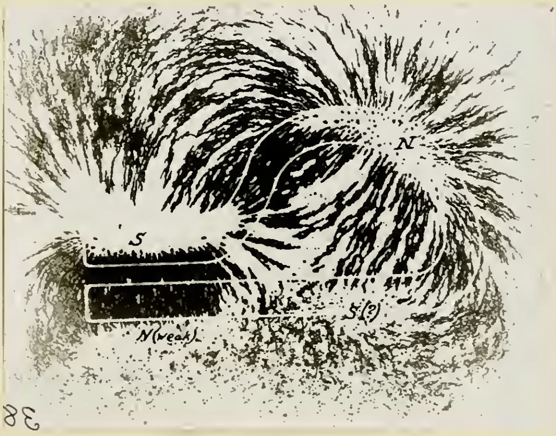
Data Sheet 43.

INSTITUTE OF TECHNOLOGY



Magnet Z Data Sheet 43.

35



Magnet X Data Sheet 43.

36

ARMOUR
[illegible]
LIBRARY

- PLATES -

PLATE - I.

INSTITUTE OF TECHNOLOGY
LIBRARY

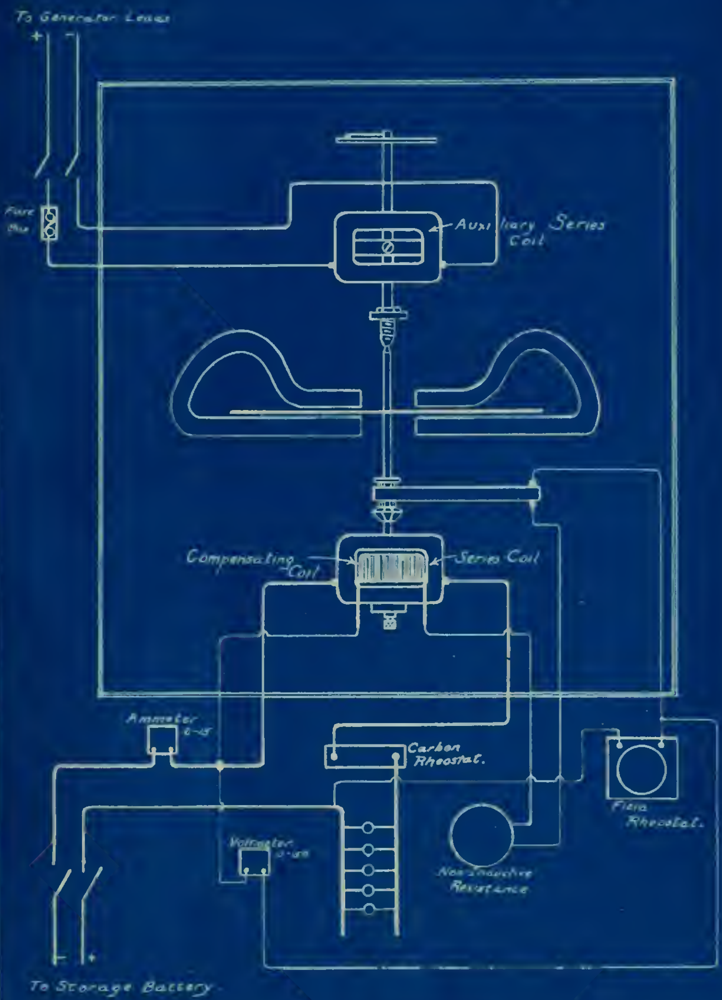
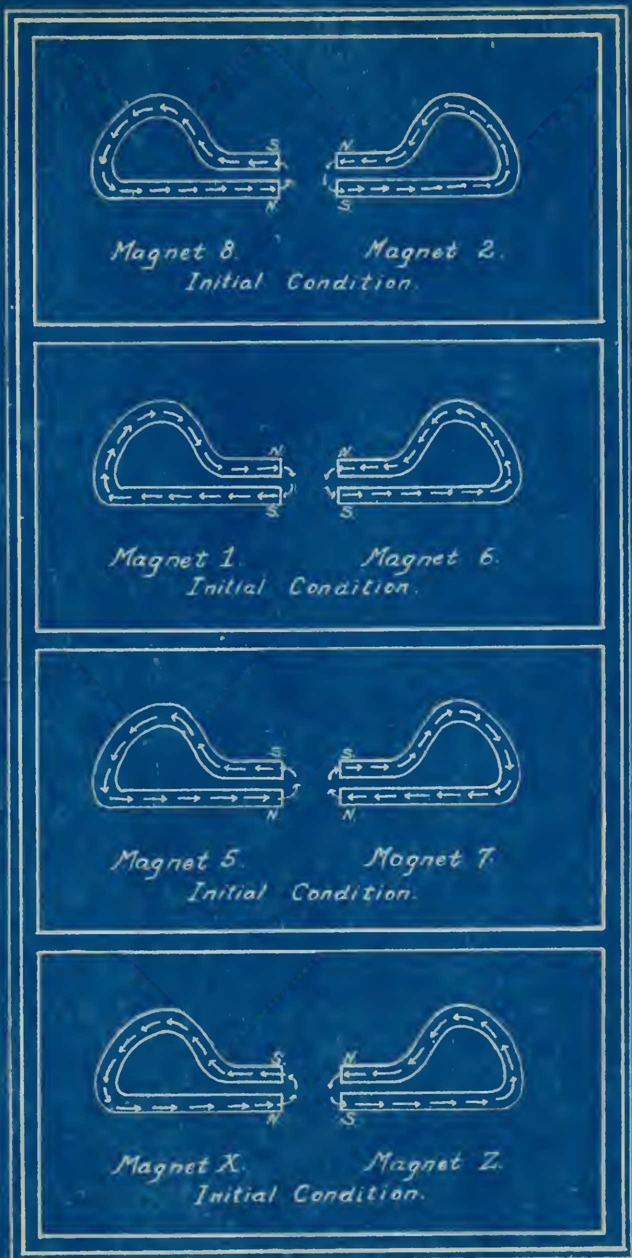
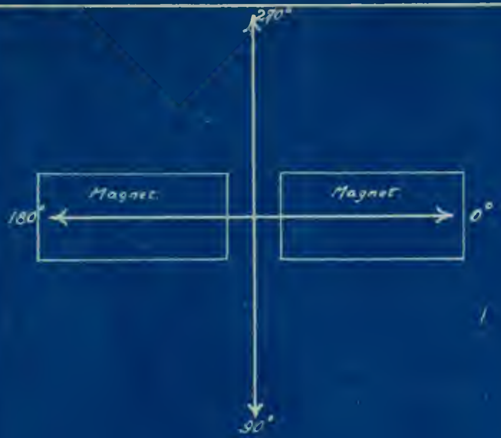


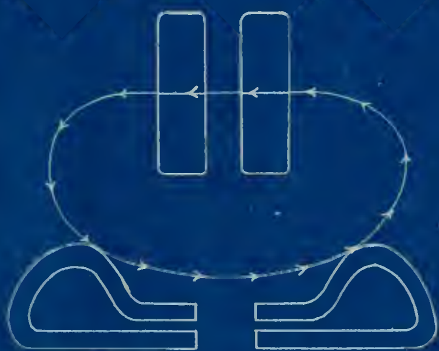
Diagram of Apparatus and Wiring.


S.
N.
N.
S.
Magnet 8.
Magnet 2.
Initial Condition.
N.
S.
N.
S.
Magnet 1.
Magnet 6.
Initial Condition.
S.
N.
S.
N.
Magnet 5.
Magnet 7.
Initial Condition.
S.
N.
N.
S.
Magnet X.
Magnet Z.
Initial Condition.

INSTITUTE OF TECHNOLOGY
LIBRARY.



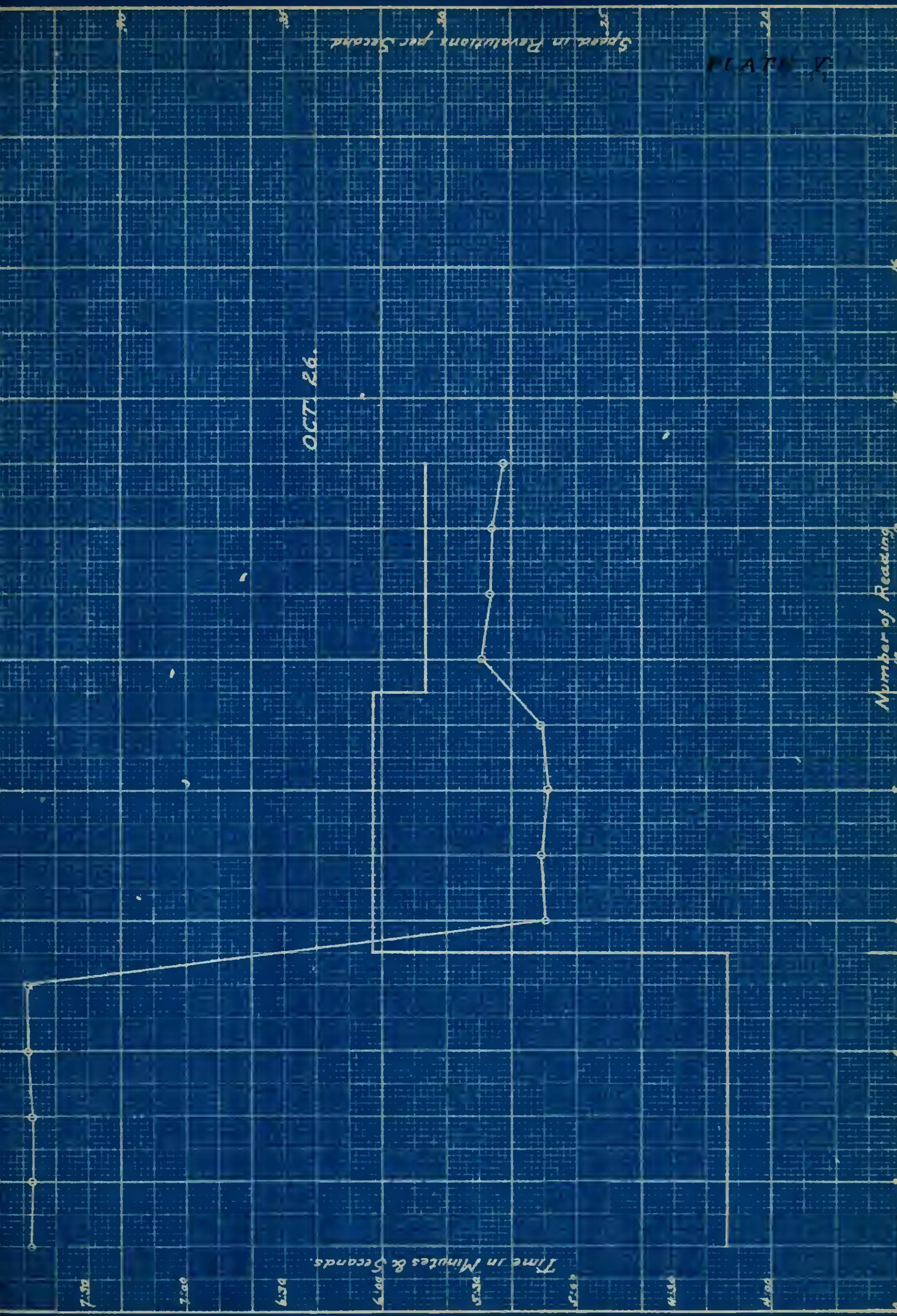
-Top View-
Direction of Momentary Fields.



-Front View-
Direction of Momentary Field-0°

ARMOUR
INSTITUTE OF TECHNOLOGY

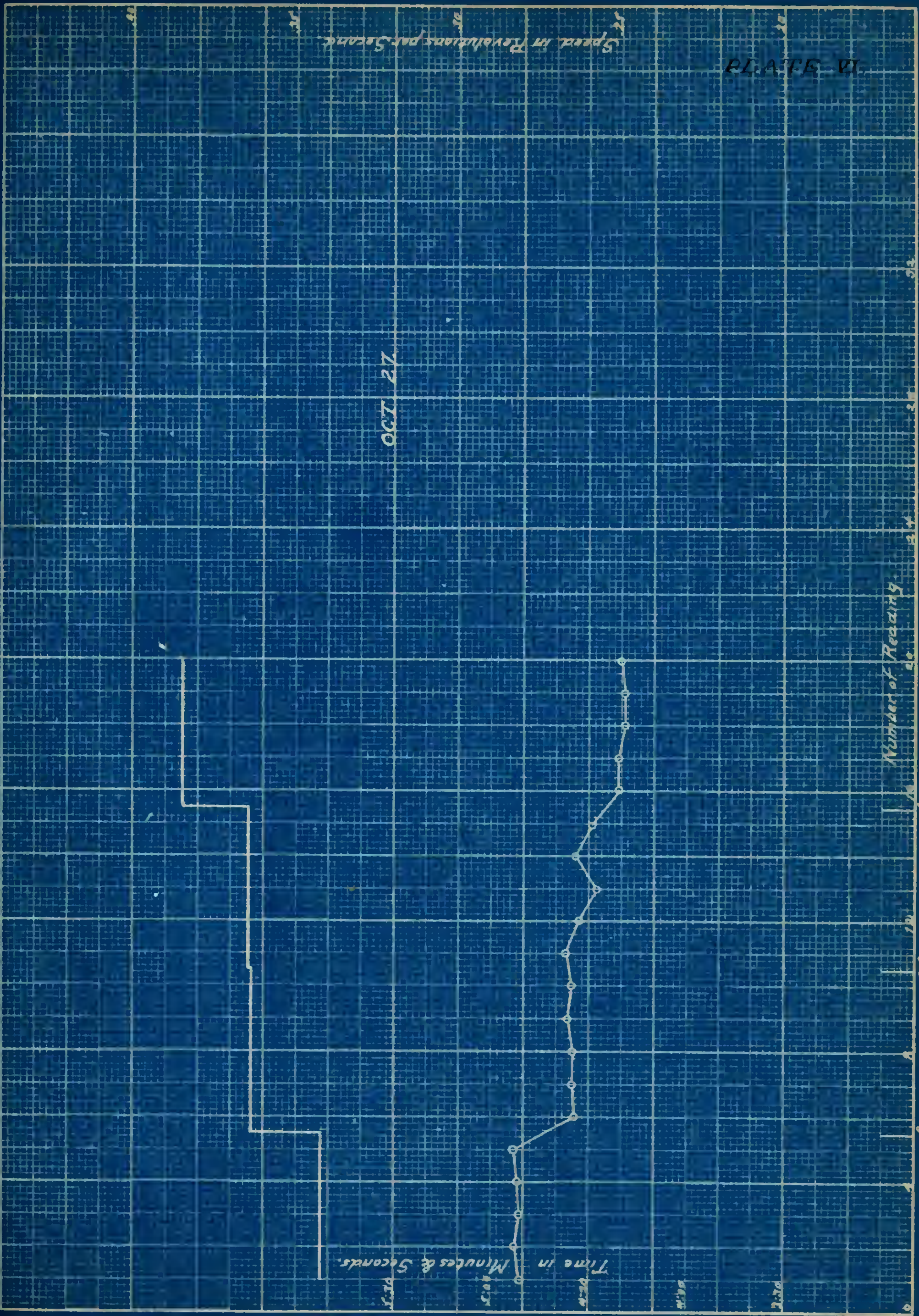
PLATE V.



Speed in Revolutions per Second
OCT. 26.
Number of Reading
Time in Minutes & Seconds.

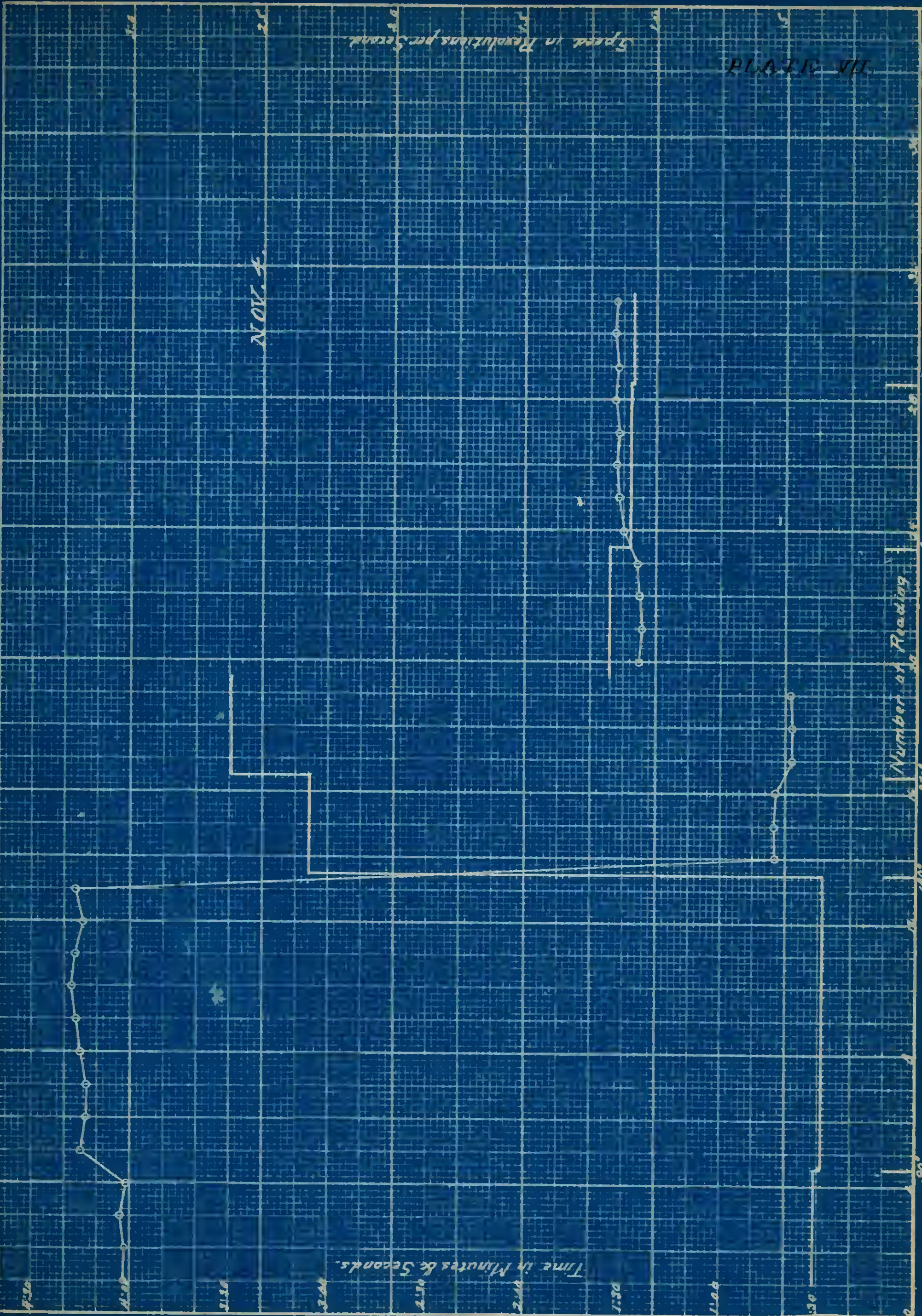
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

PLATE VI.


Speed in Revolutions per Second
OCT. 27
Number of Reading
Time in Minutes & Seconds.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

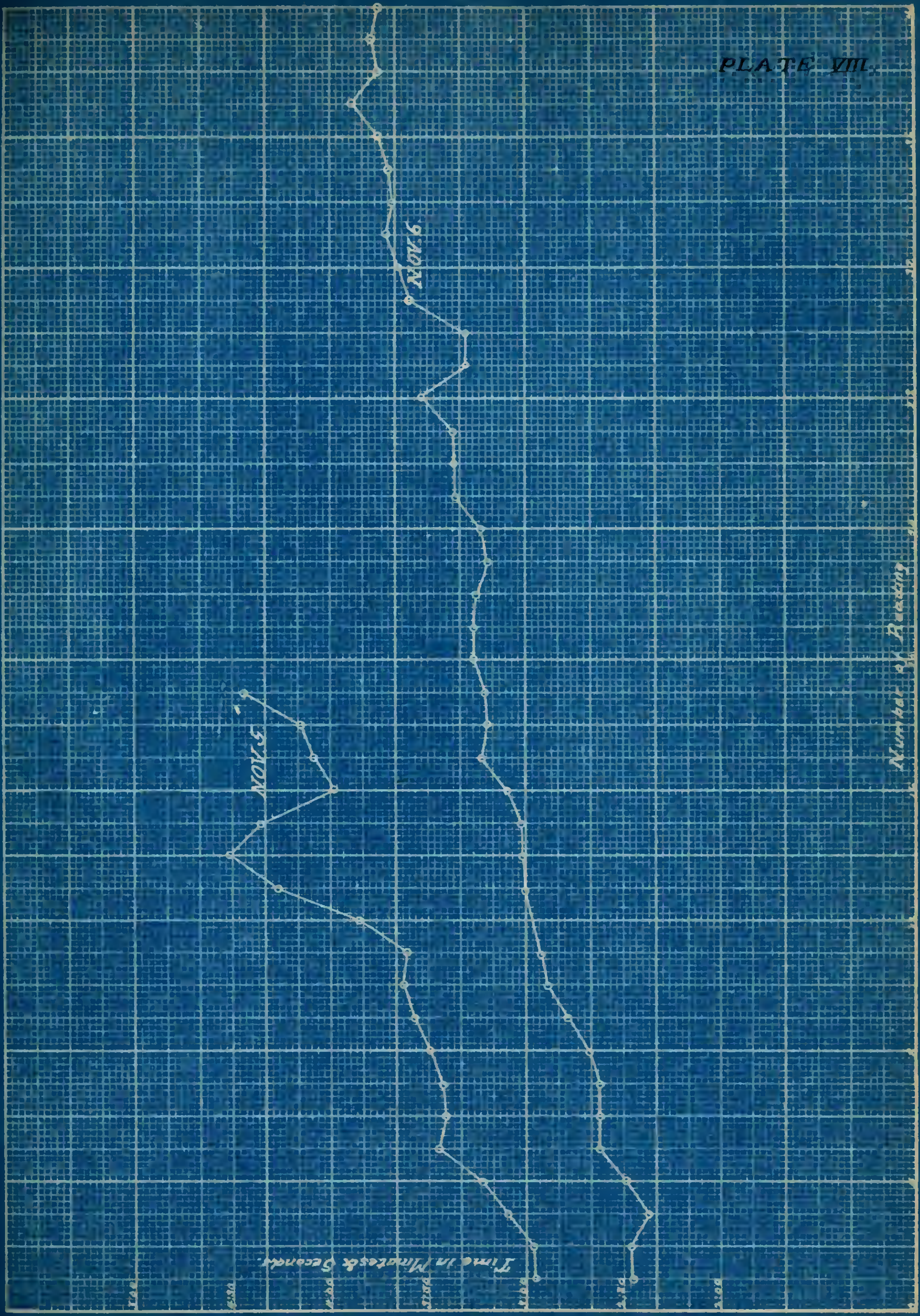
PLATE VII.



Speed in Revolutions per Second
Nov. 4
Number of Reading
Time in Minutes & Seconds.

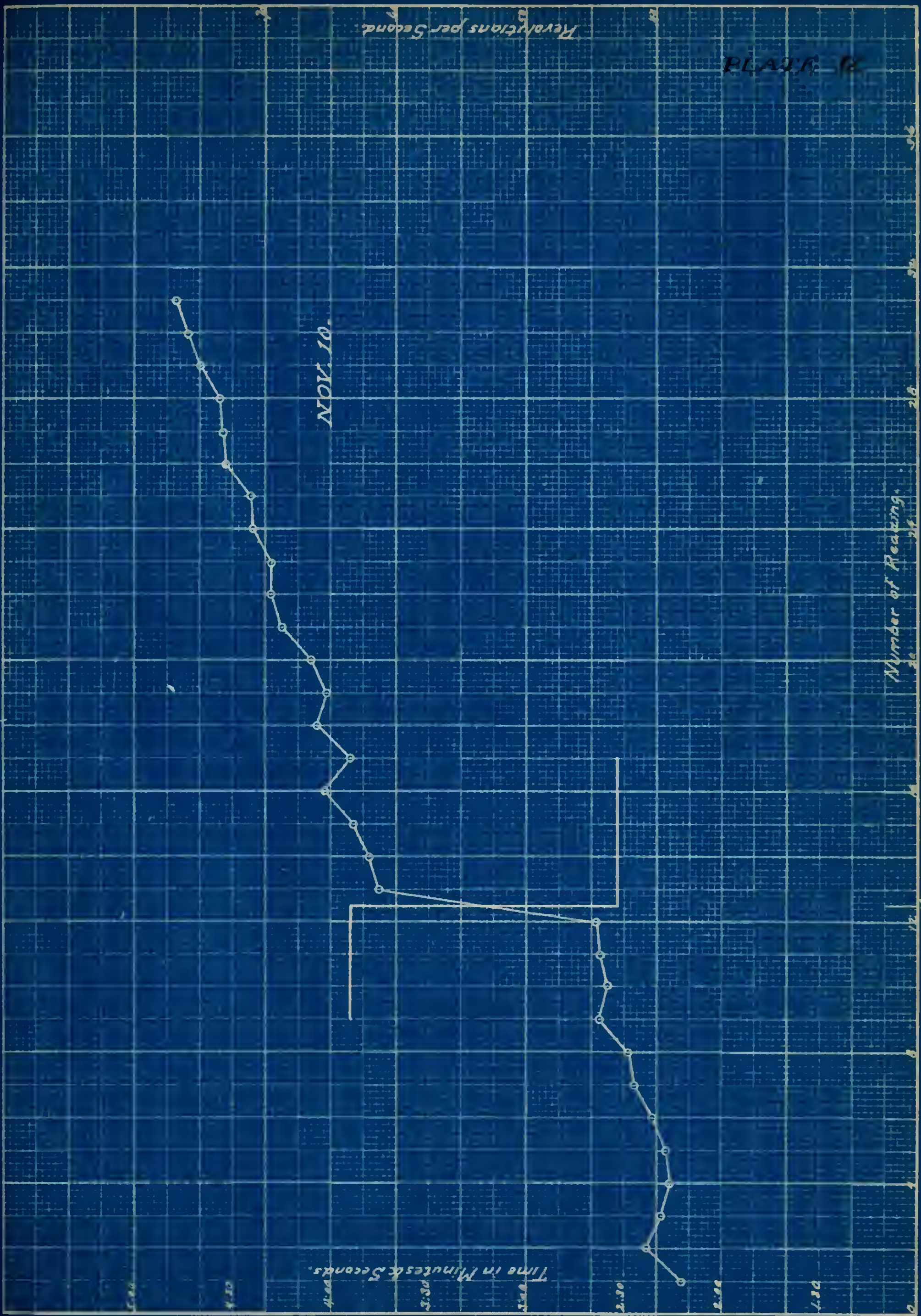
ARMOUR
INSTITUTE OF TECHNOLOGY

PLATE VIII.



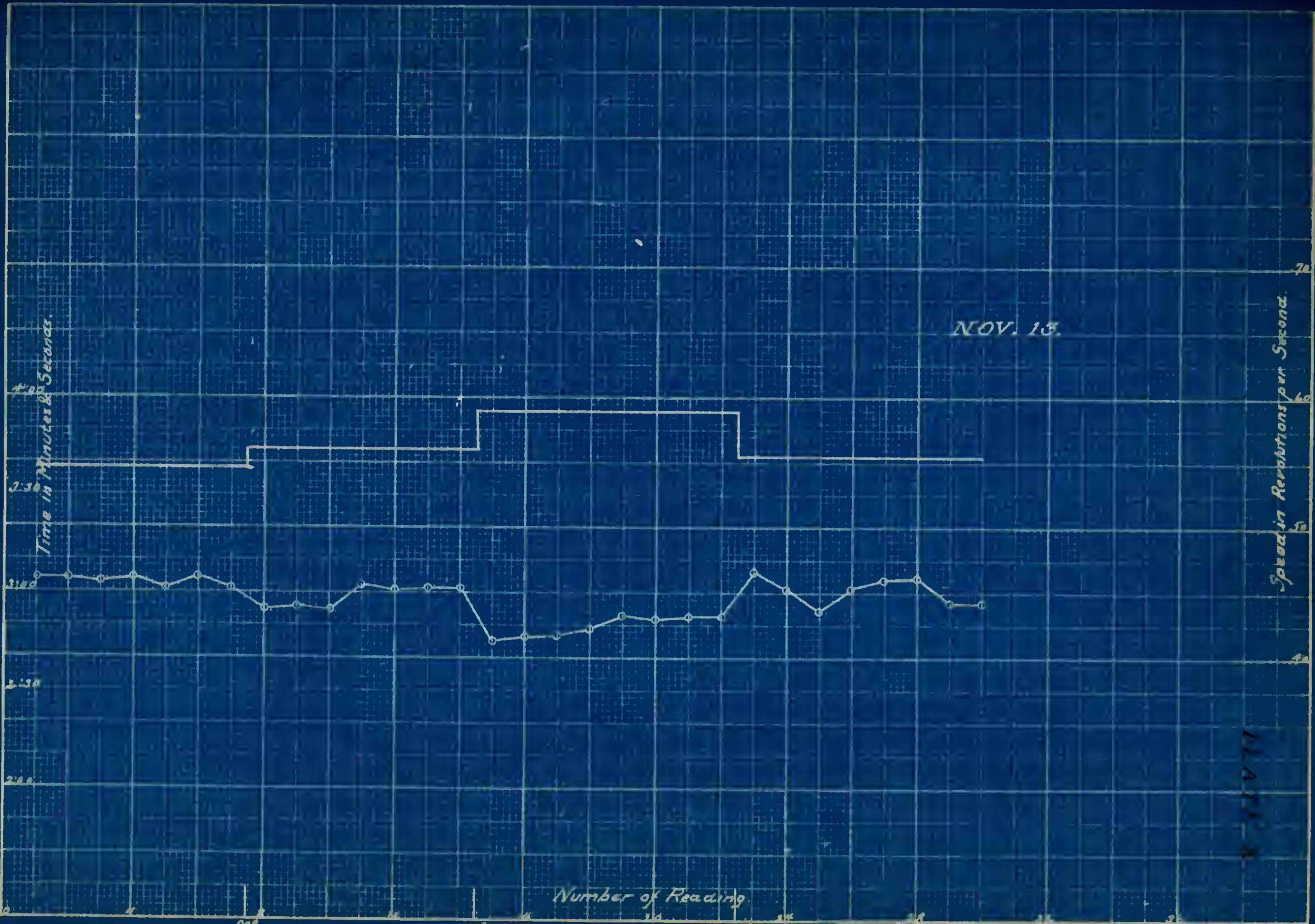
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

PLATE 12

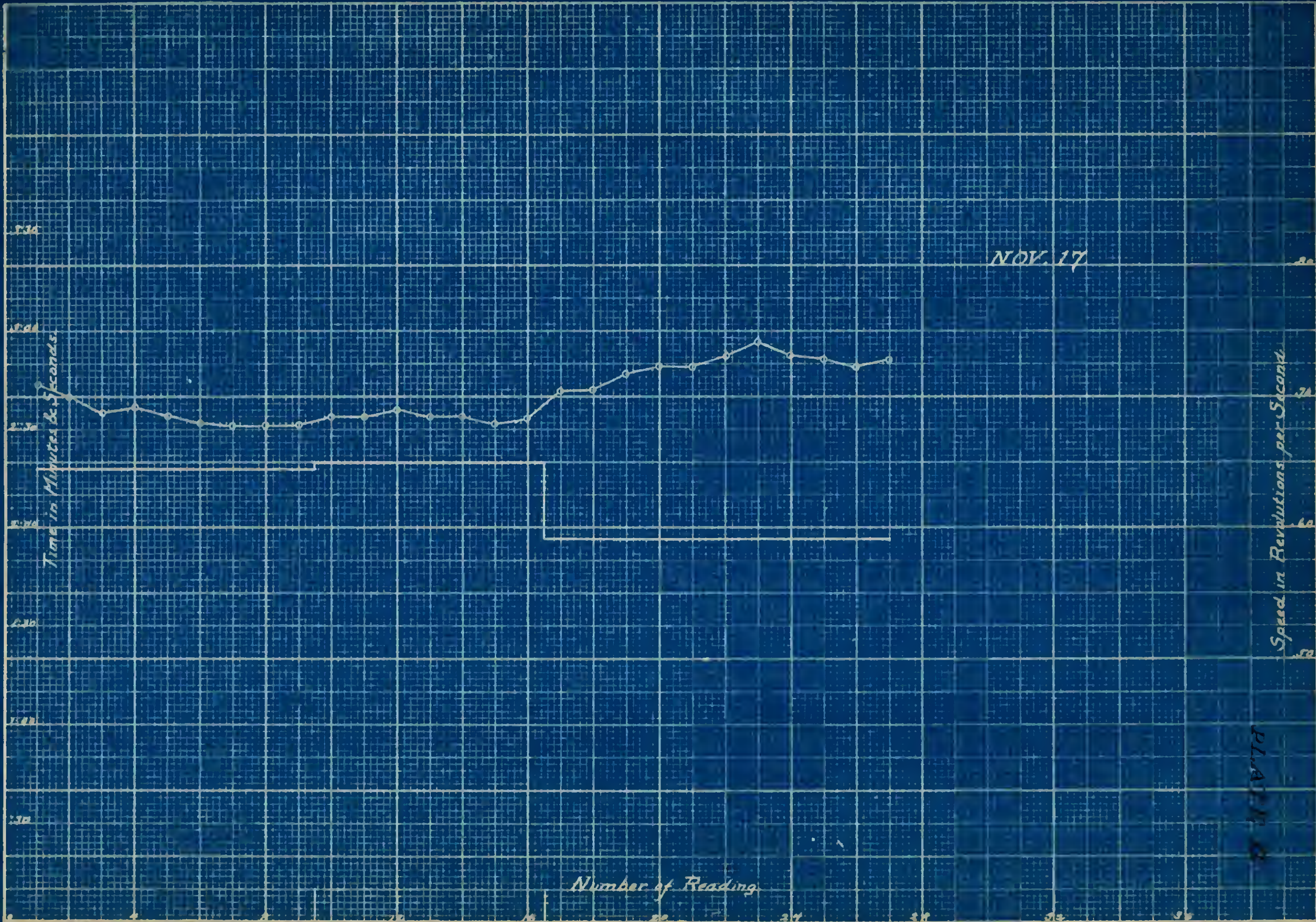


Revolutions per Second
NOV. 10.
Number of Reading.
Time in Minutes & Seconds.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY


NOV. 13.
Time in Minutes & Seconds.
Speed in Revolutions per Second.
Number of Reading.
3:00
2:30
2:00
90°
0°
90°
PLATE X

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

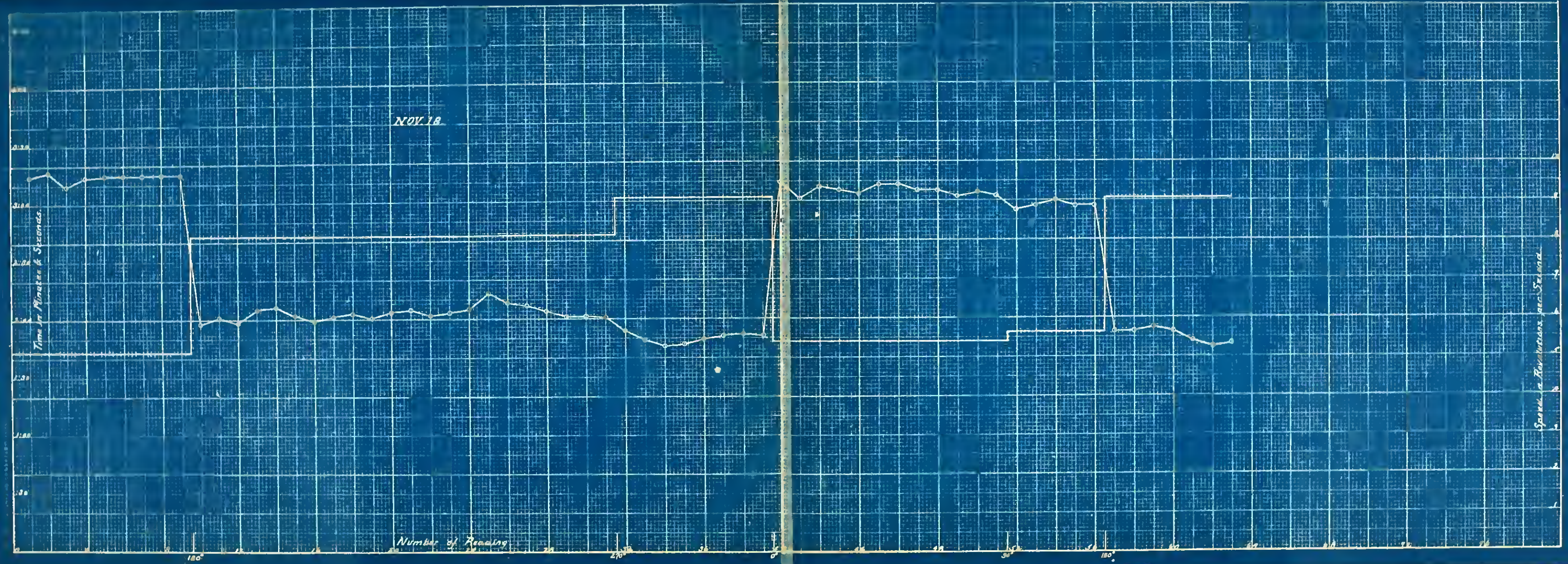


NOV. 17
Time in Minutes & Seconds.
Speed in Revolutions per Second
Number of Reading
0°
30°

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

PLATE XII.

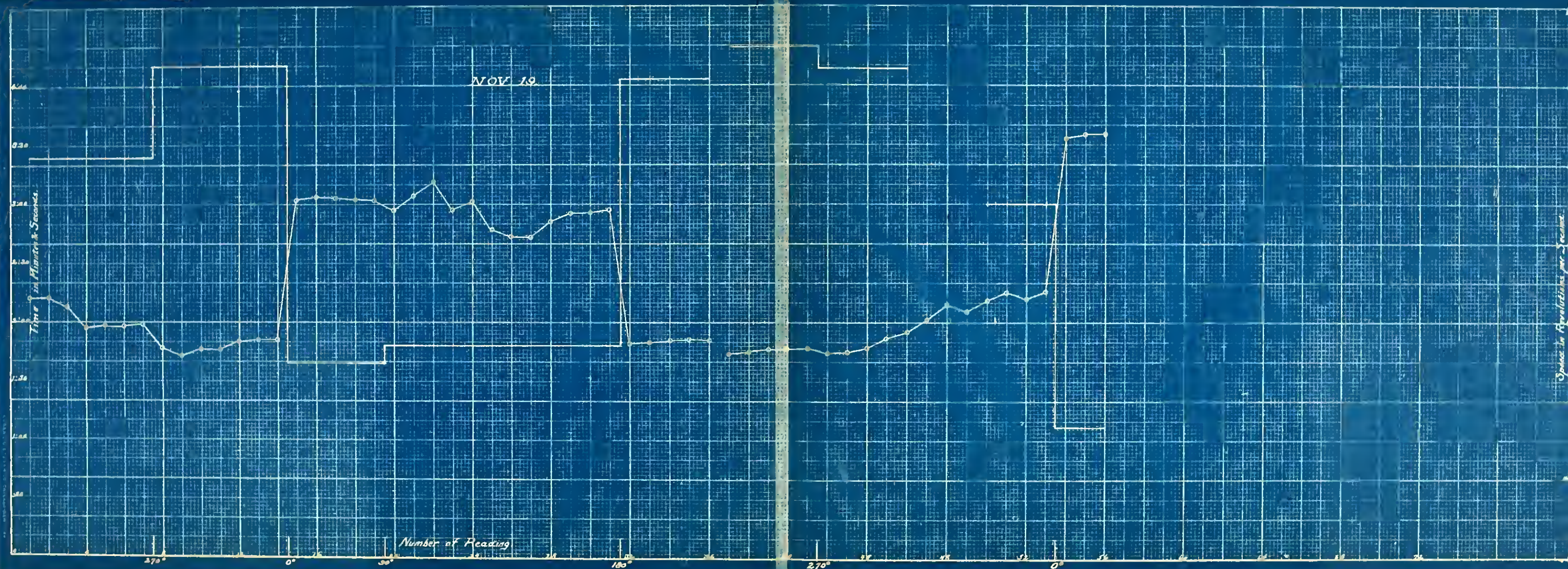
ARMOUR
INSTITUTE OF TECHNOLOGY


NOV. 18
Time in Minutes & Seconds.
Number of Reading
Speed in Revolutions per Second

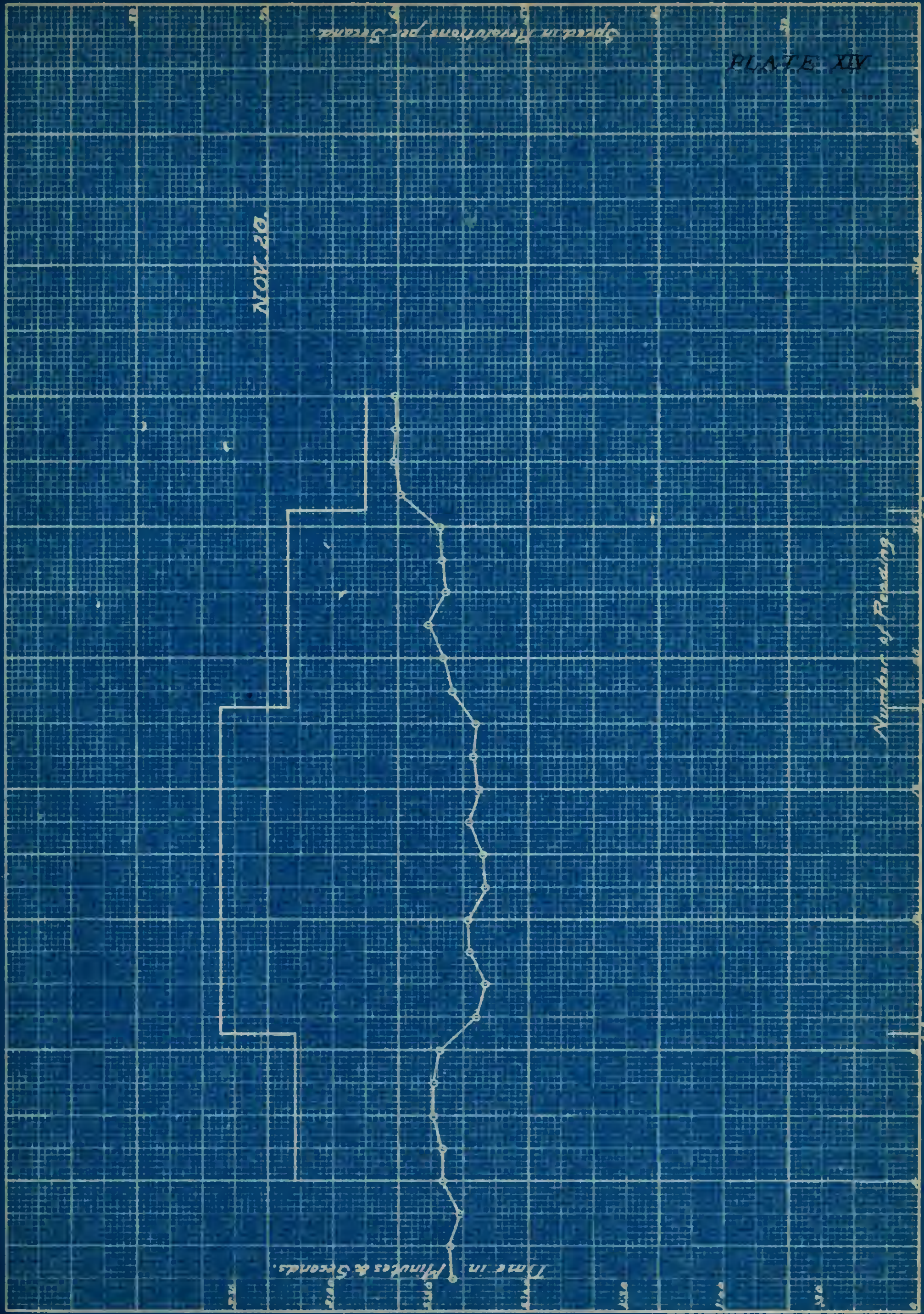
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

PLATE XIII.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY


NOV 19.
Time in Minutes & Seconds.
Number of Reading
270°
0°
90°
180°
270°
0°
Space in Revolutions per Second.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

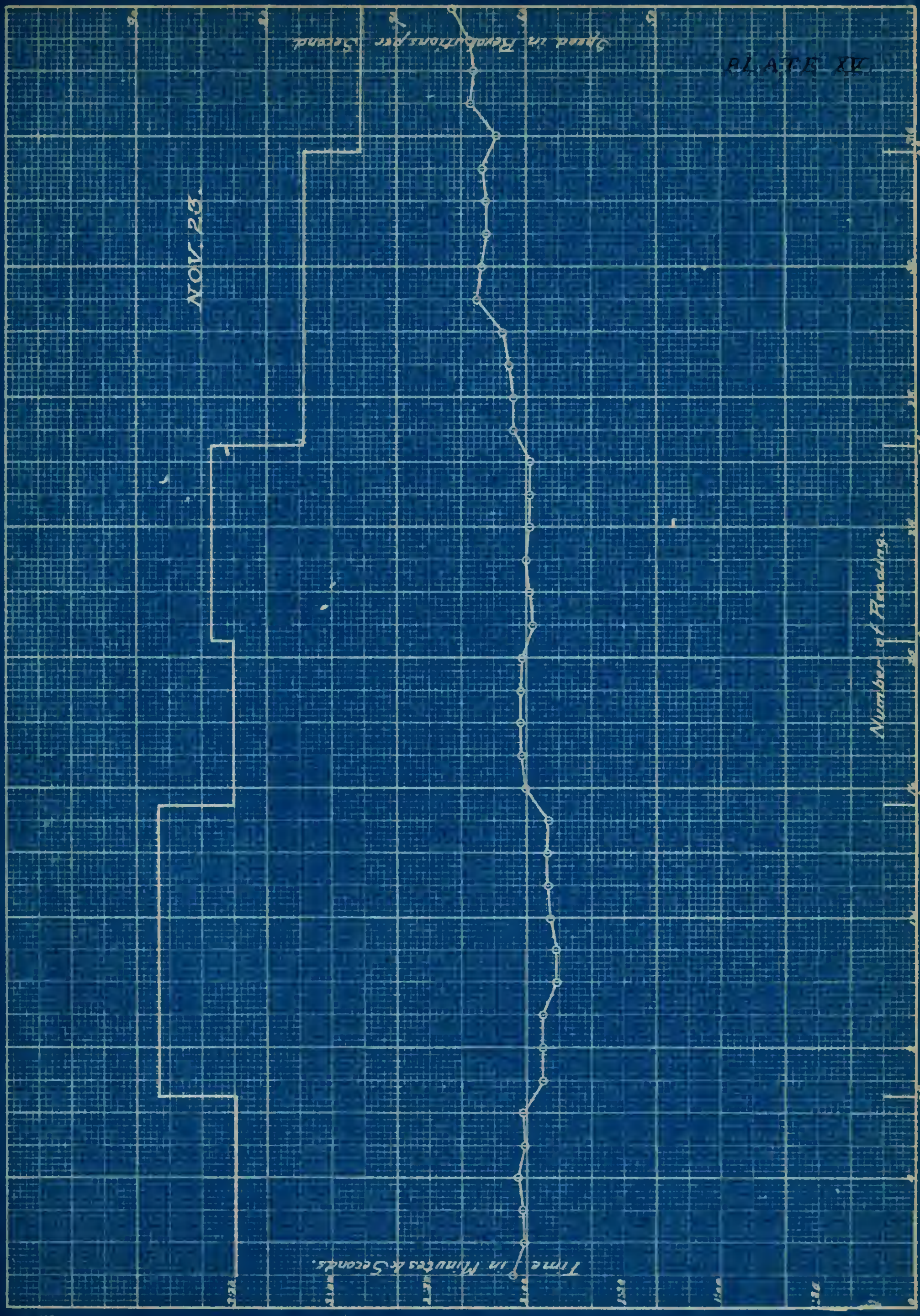


Speed in Revolutions per Second
NOV. 20.
Number of Reading
Time in Minutes & Seconds.

PLATE XIV

ARMOUR
INSTITUTE OF TECHNOLOGY
[illegible]

PLATE XV.



Speed in Revolutions per Second
NOV. 23.
Number of Reading.
Time in Minutes & Seconds.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

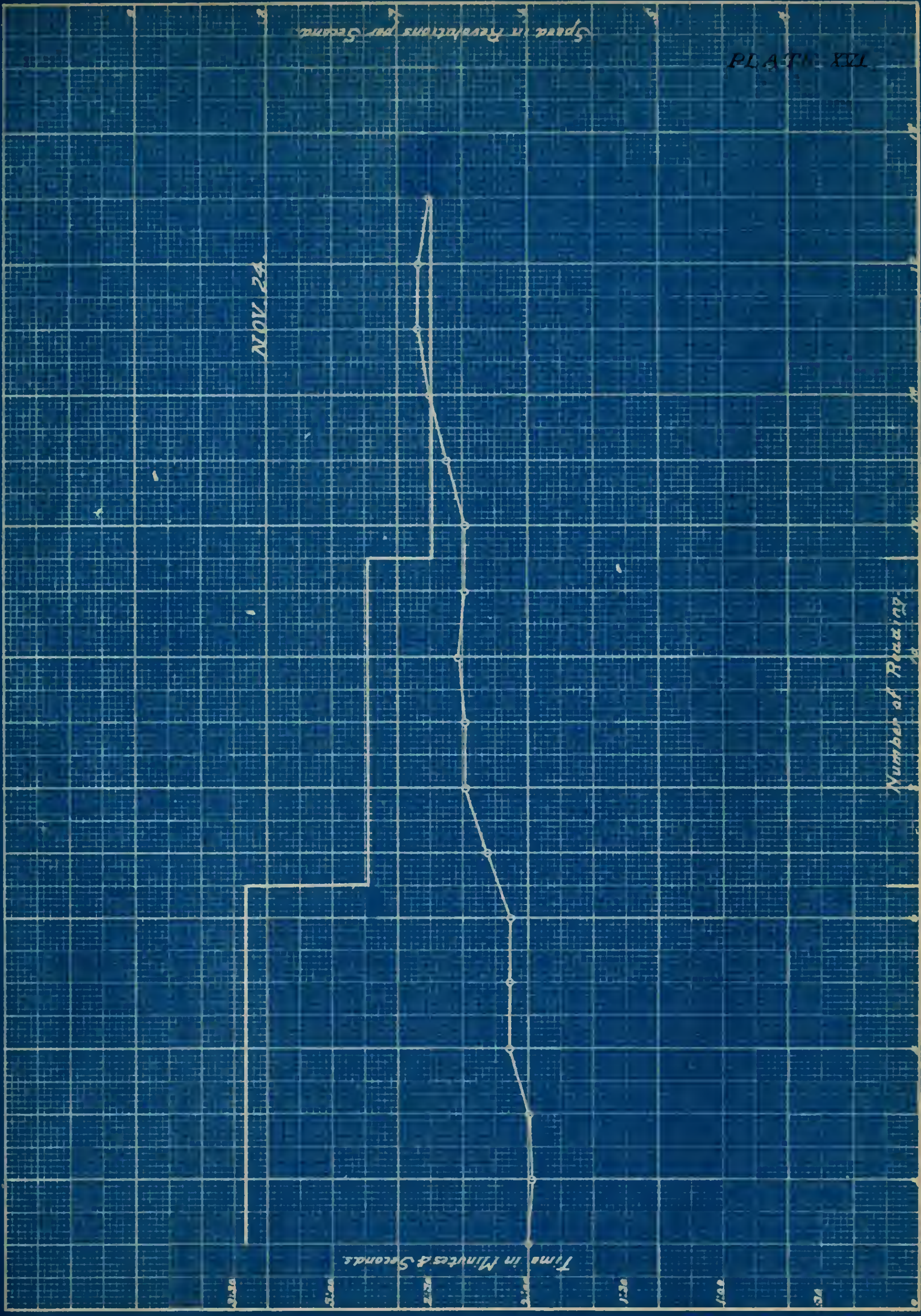

Speed in Revolutions per Second
NOV. 24
Number of Reading
Time in Minutes & Seconds

PLATE XVI

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

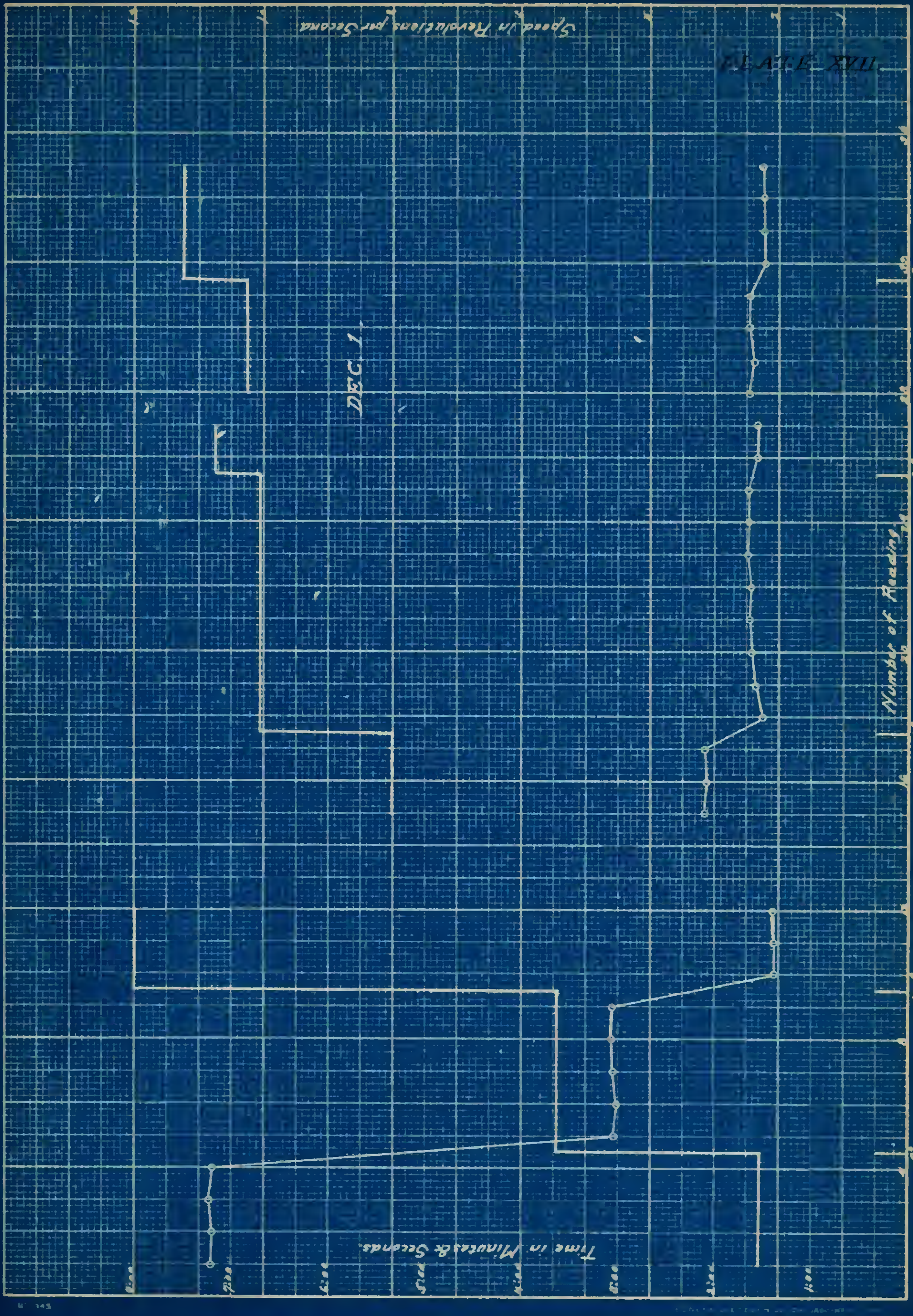
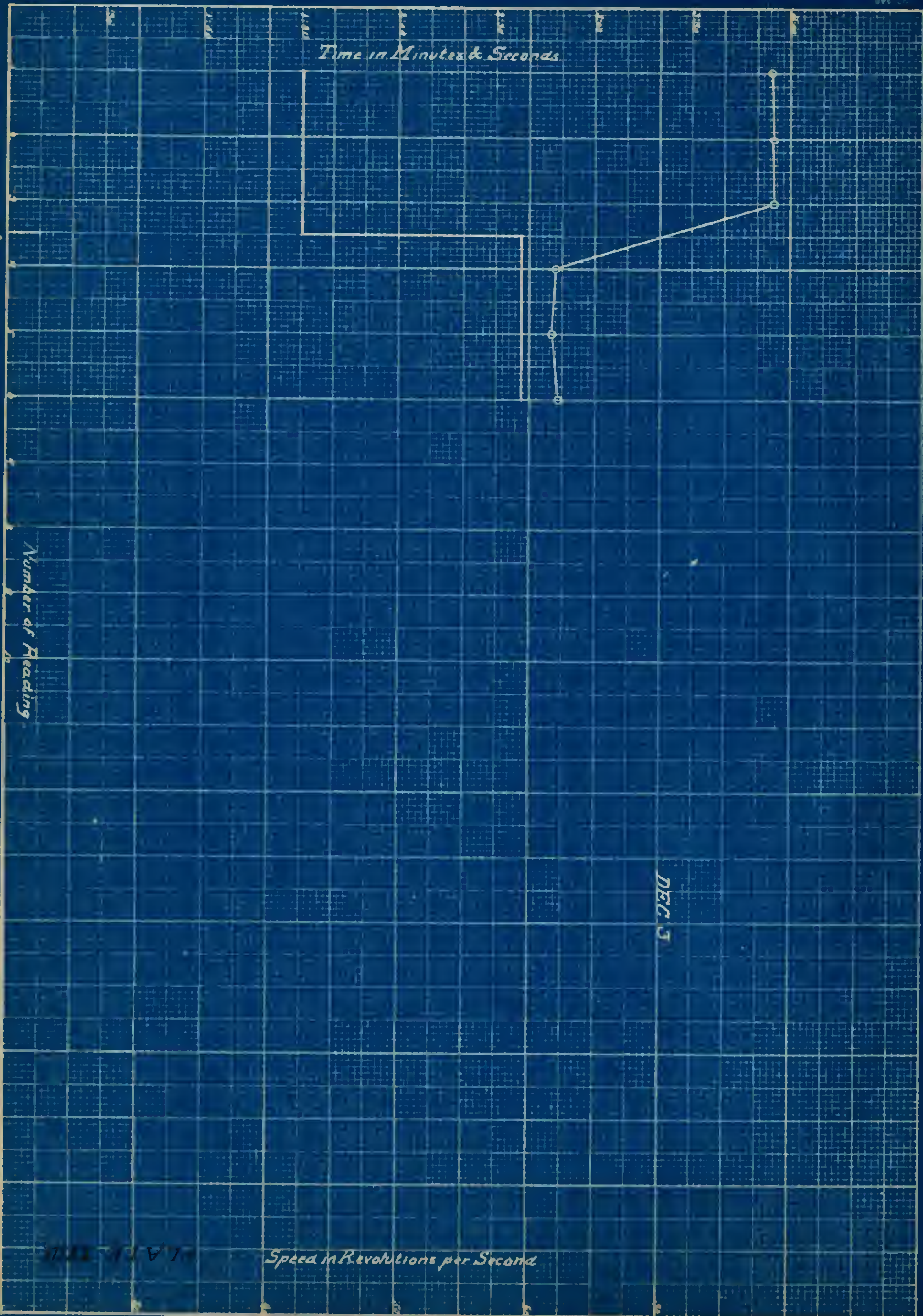


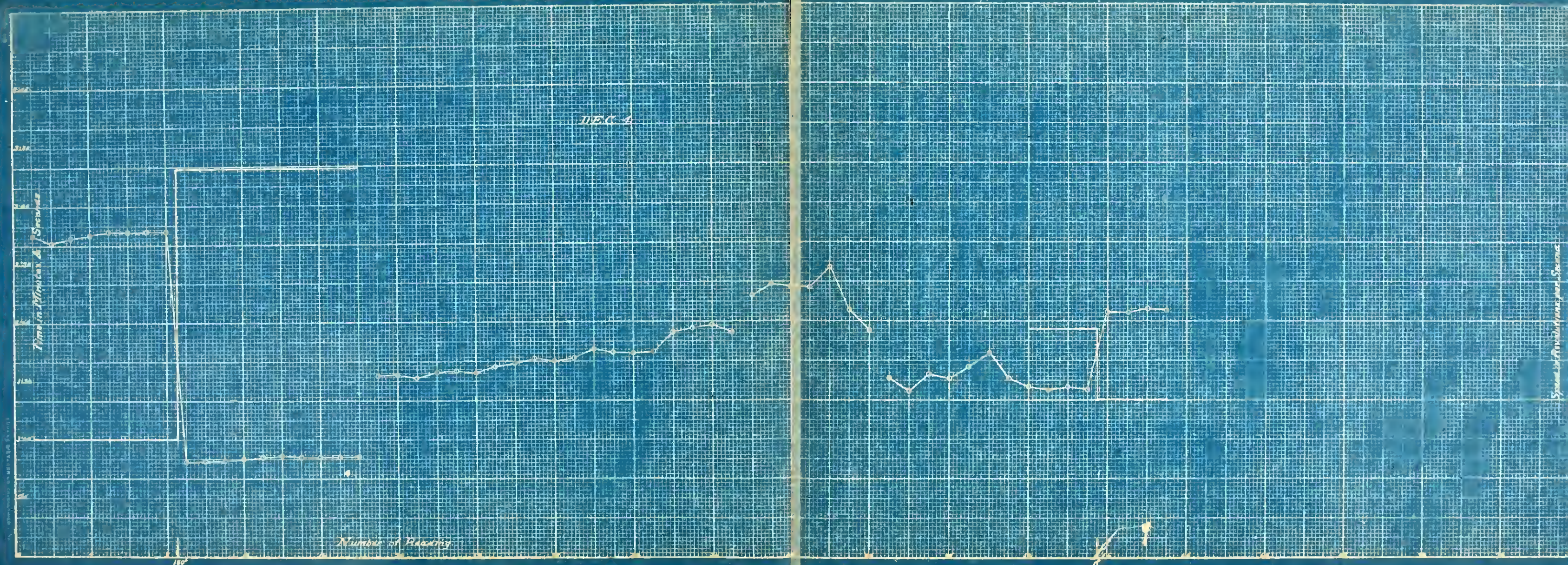
PLATE XVII.
Speed in Revolutions per Second
DEC. 1.
Number of Reading
Time in Minutes & Seconds.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

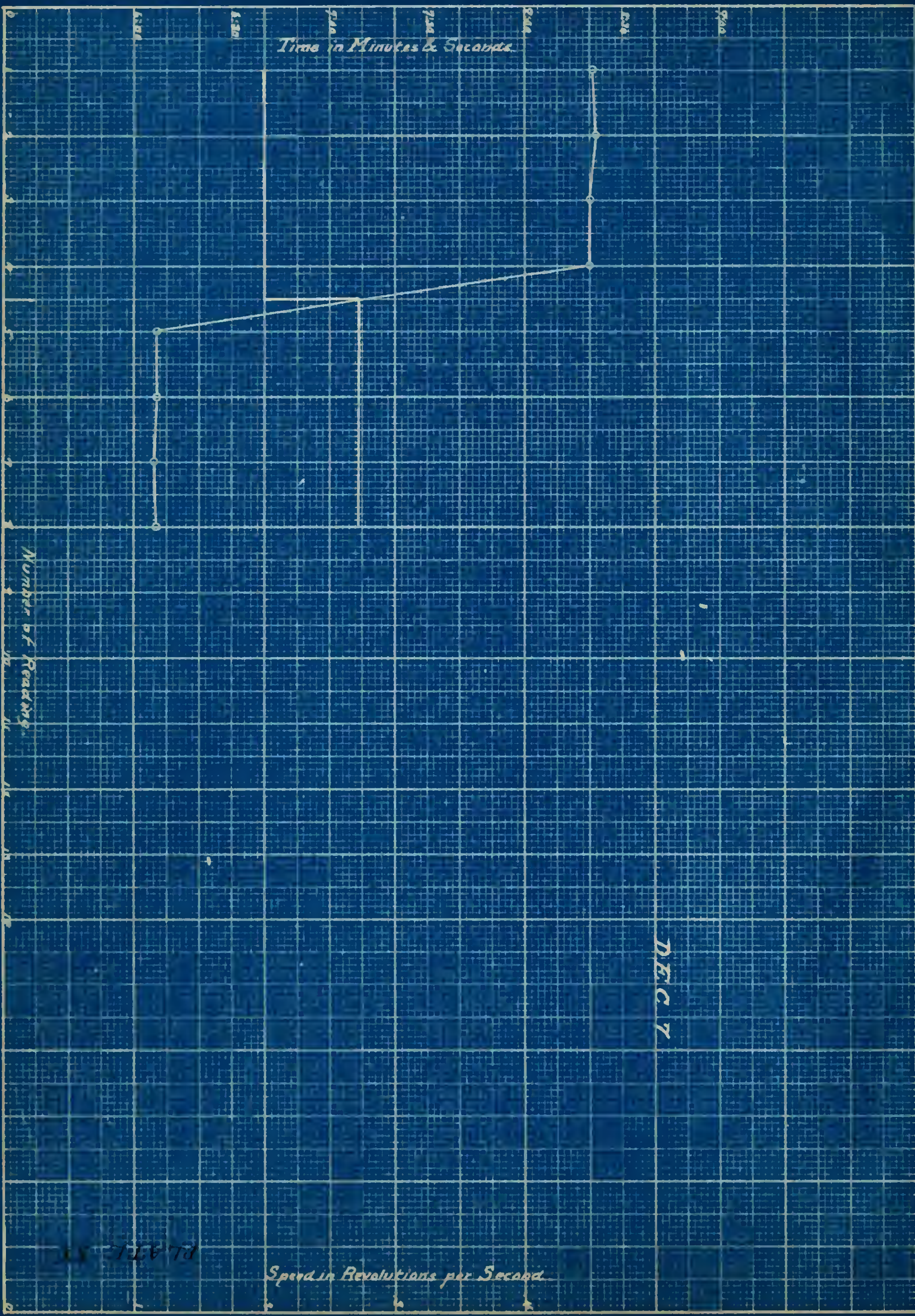

Time in Minutes & Seconds
Number of Reading
DEC. 3
Speed in Revolutions per Second

ARMOUR
INSTITUTE OF TECHNOLOGY

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY


DEC. 4
Number of Reading

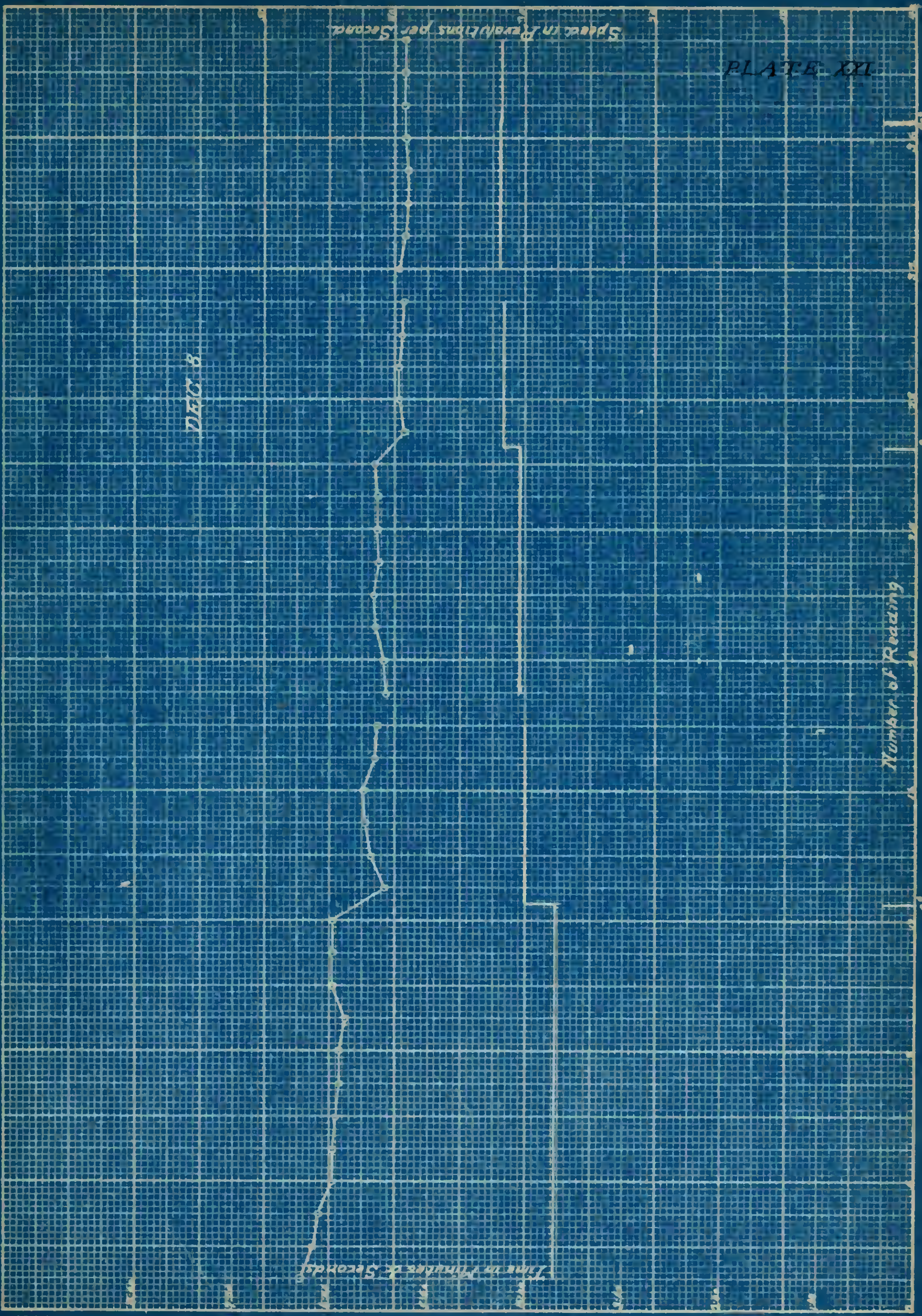
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY



Time in Minutes & Seconds
Number of Reading
DEC 7
PLATE XV
Speed in Revolutions per Second

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

PLATE XXI



Speed in Revolutions per Second
DEC 8
Number of Reading
Time in Minutes & Seconds

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

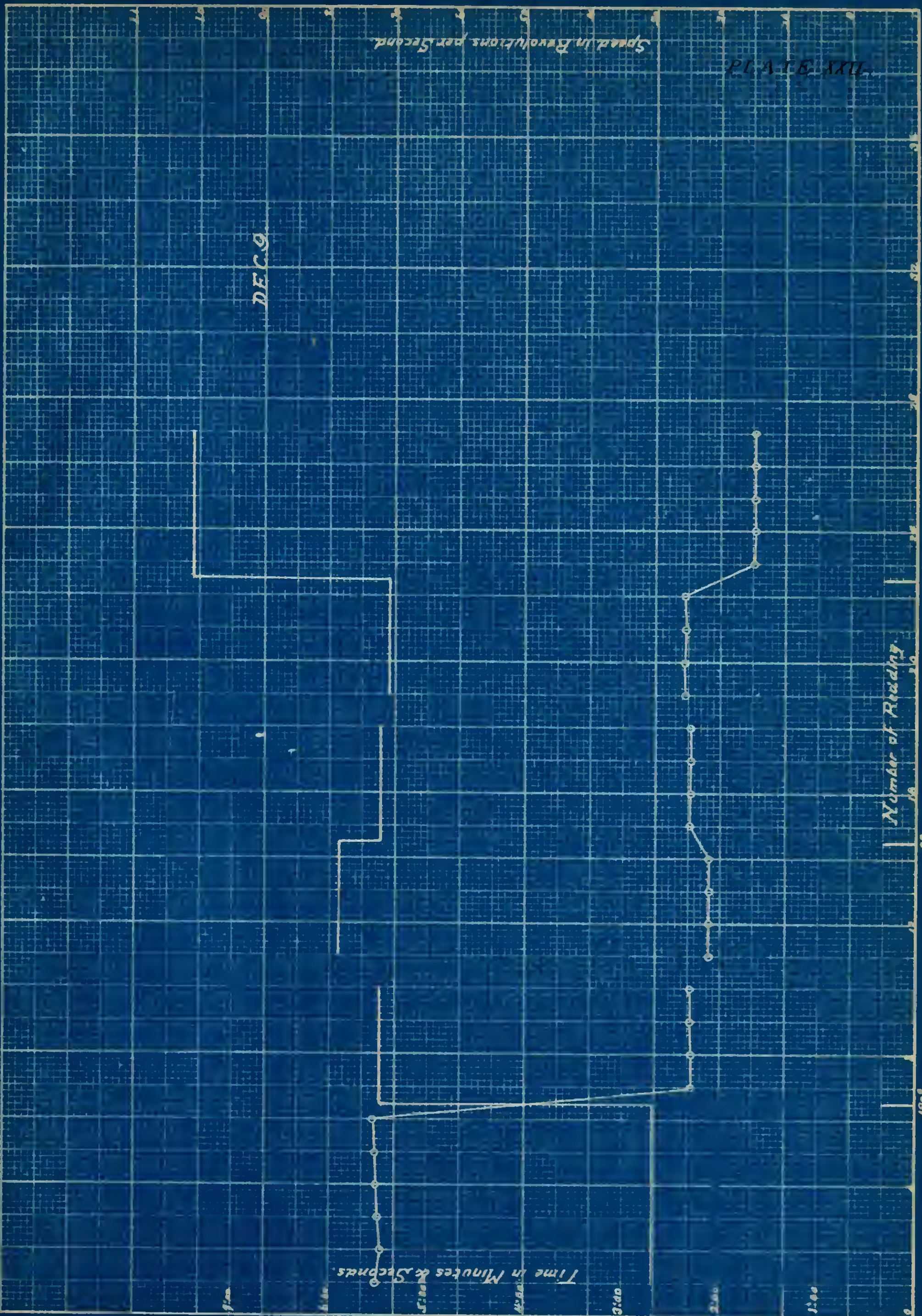
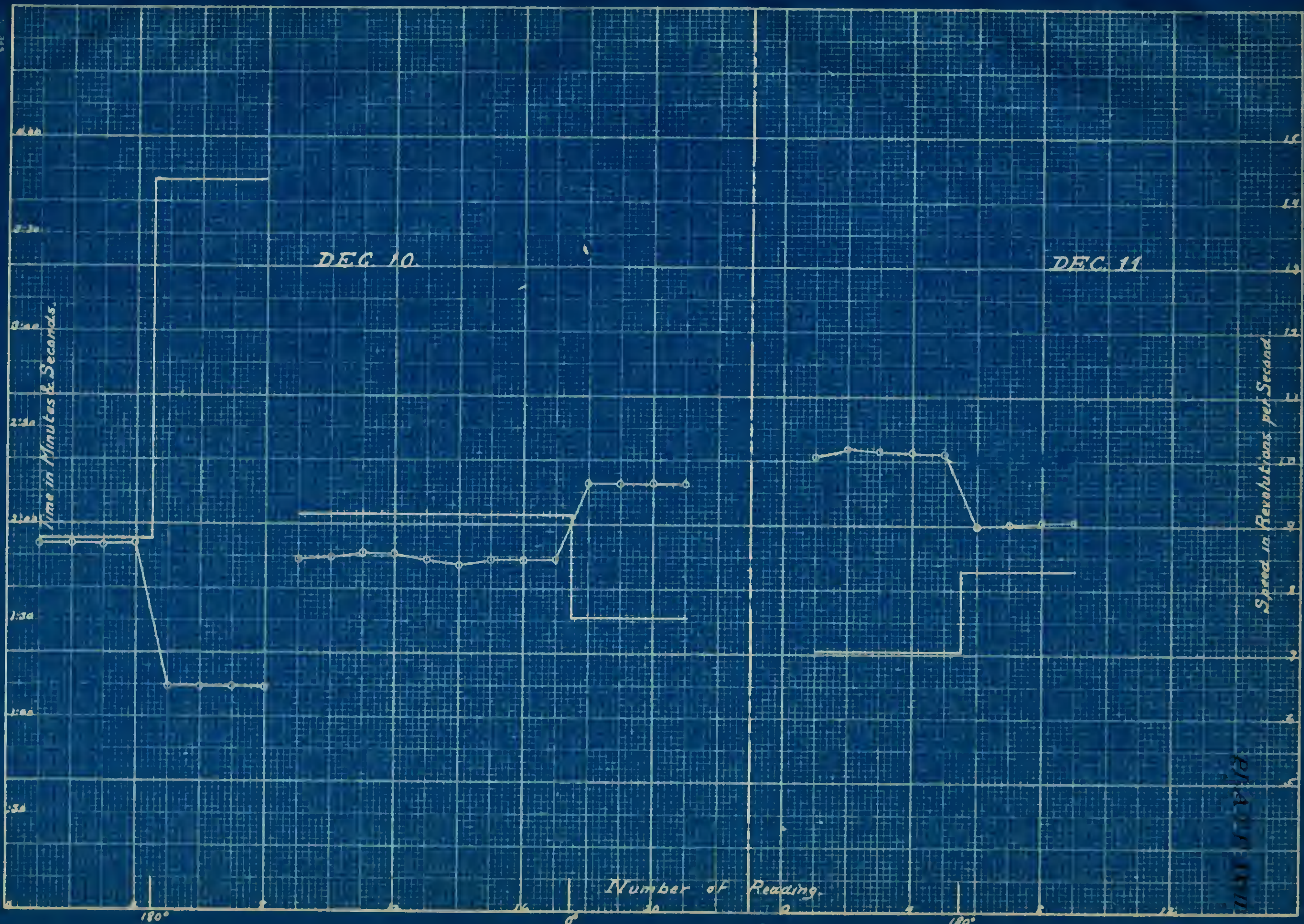


PLATE XXII.
Speed in Revolutions per Second
DEC. 9
Number of Reading
180°
0°
180°
Time in Minutes & Seconds

ARMOUR
INSTITUTE OF TECHNOLOGY

PLATE XVII


DEC. 10.
DEC. 11
Time in Minutes & Seconds.
Speed in Revolutions per Second
Number of Reading.
180°
0°
180°

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY